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Technologies and Management Strategies for Hazardous Waste Control

Volume II—Working Papers

Part D

Alternatives for Reducing Hazardous Waste Generation Using End-Product Substitution

April 1983

CONGRESS OF THE UNITED STATES
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Preface

This volume contains papers written for OTA to assist in preparation of the report *Technologies and Management Strategies for Hazardous Waste Control.* OTA does not endorse these papers. In several instances, the OTA report reaches somewhat different conclusions because of additional information which was obtained later. These papers, however, may prove valuable for readers needing more detailed or specific information than could be accommodated in the final assessment report, and are being made available for such purposes.

ALTERNATIVES FOR REDUCING HAZARDOUS WASTE GENERATION USING END-PRODUCT SUBSTITUTION

Prepared for
Office of Technology Assessment
U.S. Congress

Prepared by
Sterling Hobe Corporation

February 1982

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EXECUTIVE SUMMARY

Review of the literature on end-product substitution suggests that such substitutions take place continuously in many sectors of industry. Both consumer and industrial end-products are substituted for by other end-products.

Few end-product substitutions have been undertaken explicitly for the purpose of reducing hazardous waste generation at the point of manufacture. More often, end-products are substituted because of occupational health considerations during the manufacturing operations as well as during the life cycle of the end-product (i.e. pesticides, PCBs DEPHs, PVCs, certain end-products containing asbestos).

End-product substitution takes place also for a number of other reasons which include:

Obsolescence of the existing end-products;

Reduced manufacturing costs of the substitute end-products;

Improved design of the substitute end-products;

Changes in consumer tastes; and

Development of new end-products.

Clearly while some end-product substitution takes place because of environmental considerations, there are many other factors which encourage such substitutions. Furthermore, while it is very difficult to explicitly isolate end-product substitutions from changes in manufacturing technologies employed and/or from changes in raw materials or inputs, it is safe to say that most, if not all, of the end-product substitutions are also accompanied by changes in production processes and/or inputs.

Furthermore, most end-products which generate hazardous wastes during their manufacture may generate hazardous waste during their entire life cycle and remain hazardous at the time of their disposal.[1]

It is important to note also that any one specific substance which is responsible for hazardous waste may be used in numerous end-products. For example, DEHP is used as a plasticizer in a very wide spectrum of various plastic products. Likewise, asbestos is used in some dozen or more applications.

This immediately suggests that even a complete substitution of one specific end-product which generates hazardous wastes by another may not result in the complete elimination of hazardous waste generation and discharge into the environment. Indeed, the case studies presented in this report suggest that for such hazardous wastes as asbestos, complete substitution for asbestos in one end-product application, even if it is a major use of asbestos, say asbestos-cement pipe, results only in a 30 percent reduction of asbestos waste generation. Note further that hazardous waste generation for many end-products occurs during the use of the end-product or at the time of discharge and that in some cases the useful life of the end-product is exceptionally long (i.e., asbestos again but used as a structural element in building), and therefore there will be discharges of hazardous wastes into the environment for some time after complete end-product substitution has taken place.[1]

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[1] For example, Askarel transformers, asbestos floor tile, asbestos used as fricton materials, cadmium used in automotive tires, and the use of DEHP in various plastic products.

For most end-products which generate hazardous wastes there indeed exist substitute end-products which are less harmful and/or which generate reduced quantity of hazardous wastes, or which are more acceptable from the point of view of environmental quality and/or public welfare. However, the literature review and the case studies suggest that in many cases the substitute end-products represent only a marginal improvement over the end-product to be substituted for. For example, substitution of DEHP for PCB's in electrical applications offers relatively little in terms of hazardous waste generation reduction. In the case of DEHP, when used as a plasticizer, all of the substitute compounds generate hazardous wastes during manufacture, although some of these are environmentally more acceptable than DEHP, because they are less persistant.

In all cases, the parties which are impacted by the end-product substitution include the manufacturers of the end-products and the users of the products, either the general public or industrial consumers.

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[1] In the case of asbestos used as construction material, for example, asbestos becomes an airborne pollutant at the time of demolition. Note that in the event there is a deliberate policy to recall all of the end-products in use (as was the case of PCB), this recall and disposal of such end-products may be very costly.

In addition, end-product substitution may impact the suppliers of goods and services to the manufacturers of both the end-products to be substituted for as well as the substitute end-products. Other parties which may be impacted by such substitution include exporters and importers of end-products, manufacturers of durable equipment used in the production of the end-products, and R&D laboratories engaged in the activities related to the substitute end-product development.

The magnitude of economic impacts resulting from end-product substitution vary, of course, among end-products as well as parties impacted. In very general terms such impacts, at least as indicated in the case studies presented in this report, appear to be not significant to all parties concerned.

There are three principal reasons for this. First, for almost all end-products one or more substitute end-products are already being used in certain applications and conditions.

Thus, substitution does not require research and development activities and introduction into the market of a brand new end-product. Rather, end-product substitution requires that the substitute end-product be allowed and/or encouraged to obtain an even increasing market share at the expense of the end-product to be substituted for.

The second reason for the relatively limited economic impacts resulting from end-product substitution is that in many cases the substitute end-product is manufactured and marketed by the firm(s) and/or sector(s) of economy which manufactured the original end-product.

This in turn requires only that the firm(s) and/or sector(s) of economy alter their lines of business within the existing structure of the firm(s) and/or sector(s) of economy, rather than shift production of certain end-product(s) from one sector of economy to another.

The latter, of course, would create significant inter-sector adjustment problems and increase the impacts from end-product substitution. The fact that there already exist for most end-products to be substituted for several substitute end-products supports a third finding from our literature search and case studies: namely that one-for-one end-product substitution seldom occurs. Rather, in the cases where an end-product is substituted for there are several substitute end-products, each best suited for specific applications in which the end-product to be substituted for was originally used.

As already noted the end-product substitution may significantly reduce hazardous waste generation. The case studies undertaken have shown that this reduction ranges from 10 percent to almost 50 percent of the original volume of hazardous waste generation. However, the magnitude by which hazardous waste generation is achieved using end-product substitutions depends on several factors. These include the extent to which the hazardous substance is used in other end-products, the specific locus where hazardous waste generation occurs (i.e., at the point

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of manufacture, in use, at the time of discharge), and the generation of the hazardous waste from other man-made activities. Economic feasibility studies of end-product substitution require a systems approach which includes a total of four major components:

- Technical and engineering analysis;
- Market factor study;
- Financial evaluation; and
- Economic analysis.

Analyses of various government policies and regulations suggest that a large proportion of these have direct impact on end-product substitution. These include government funded R&D activities, government procurement policies, government tax policies (because these impact on innovation and therefore on substitute end-product development), and environmental and occupational health and welfare regulations.

INTRODUCTION

The Office of Technology Assessment of the U.S. Congress has requested a study which analyzes the potential of reducing hazardous waste generation using end-product substitution. The results of this study are presented in this report.

Specifically, this report contains material in response to the three tasks which comprise the Statement of Work under contract #133-3310.0. The tasks are as follows:

TASK 1

Review pertinent national and international literature to identify a limited but representative number of examples in the following two categories:

1) End-product substitutes that resulted in the reduction or elimination of hazardous waste generation by or essential to the manufacturing process prior to the adopted change; and
2) Examples of attempted end-product substitutions which were unsuccessful due to either technological, economic or social complications.

SHC was charged with providing for each example a complete description and analysis of the technical, economic, marketing and management details of the substitution, as well as customer (private sector) and government responses to the substitution.

In response to Task I, Chapter I of this report presents the results of our comprehensive literature review.

TASK II

Based on information gathered under Task I, and in conjunction with OTA, SHC has formulated a set of criteria (related to both incentives and disincentives affecting substitution) for the selection of candidate end-product substitutes likely to achieve a reduction or elimination of hazardous wastes. These criteria were applied, in the form of indepth analysis, to form six (6) to eight (8) candidate substitutes from categories 1) and 2) of the literature review. The selection procedures are such that they insure that the limited number of final selections are representative of the potential for applying end-product substitutions to the reduction or elimination of hazardous waste in the United States.

It is likely that more than one alternative substitution might be technically and economically feasible. In such cases, the alternatives have been rank-ordered by factors such as benefit/cost ratio, nontechnical/economic considerations, availability of required technology and raw materials from domestic as well as from foreign resources, consumer attitudes, potential for consumer education (influence), etc. These considerations shall identify the necessary inputs for the formulation of a model for evaluating the feasibility of end-product substitutions for eliminating or reducing hazardous industrial wastes.

In addition to supplying the conceptual model, and applying it to a number of future potential substitutions having particular relevance to hazardous waste stream reduction in the U.S., SHC has estimated the overall potential, on a national scale for major industry and/or waste categories, the costs and benefits of feasible end-product substitution.

Chapters II through VIII of this report contain the analyses and findings required to accomplish the objectives stated in Task II.

TASK III

SHC performed a review of past federal policies aimed at or affecting end-product substitutions. Such policies are described and their costs and benefits (economic, technical and social) are critically analyzed, and a comparative analysis and ranking of such policies given.

Chapter IX of this report contains this review and policy description.

This report was prepared by Sterling Hobe Corporation under the direction of Ivars Gutmanis. Mr. Blair Bower provided critical review of the initial draft of this report and we are very grateful for his kind and valuable contributions.

CHAPTER I

REVIEW OF LITERATURE ON END-PRODUCT SUBSTITUTION

Substitution of end-products for the purpose of preventing pollution generation during the manufacturing process and/or during the life of the end-product has been considered on a number of occasions in the past.

For example, in a study prepared for the Interagency Economic Growth Project,[1/] a literature search was undertaken to determine industry sectors where end-product modification and/or substitution resulted in pollutant generation reduction. Table 1 summarizes the principal findings of this study for selected manufacturing sectors. While this study covered all sectors of the economy, it was undertaken with very limited resources.

Nevertheless, this report, up to the present time (spring of 1981), represents the only systematic effort to analyze the impact of normative changes in end-products for all manufacturing sectors for pollution generations loads.

Unfortunately, there is also an alarming paucity of literature, data and information on end-product changes and their impact on pollution generation for specific manufacturing sectors and/or products.

[1/] Ivars Gutmanis and Adele Shapanka, Economic Costs Associated with Environmental Quality Alternatives in the United States, 1970, 1980 and 1985: An Input-Output Analysis, for Interagency Economic Growth Project, by IRT, Washington, D.C., 1976.

TABLE 1

CHANGES IN SELECTED POLLUTANT GENERATION RESULTING FROM END-PRODUCT MODIFICATION

SECTOR	SIC	POLLUTANT OR INDICATOR	CHANGES IN POLLUTANT GENERATION AS PERCENT OF 1970 LOADS	DATE CHANGE EXPECTED
Food Products	20	BOD*	- 3%	1980
Food Products	20	BOD	- 3%	1985
Food Products	20	D.S.**	- 3%	1980
Food Products	20	D.S.	- 3%	1985
Basic Steel	331	D.S.	+ 5%	1980
Basic Steel	331	D.S.	+ 5%	1985
Plastics	2831	Particulates	+ 2%	1980
Plastics	281	Particulates		1985
Glass	321	Particulates	+ 3%	1980
Glass	321	Particulates	+ 4%	1985
Cement	324	Particulates	+ 2%	1980
Cement	324	Particulates	+ 3%	1985
Paint	285	Hydrocarbons	- 7%	1980
Paint	285	Hydrocarbons	-10%	1985
Leather	31	Solid Wastes	- 6%	1980
Leather	31	Solid Wastes	-10%	1985

SOURCE: Ivars Gutmanis and Adele Shapanka, Economic Costs Associated with Environmental Quality Alternatives in the United States, 1970, 1980 and 1985: An Input-Output Analysis, for Interagency Economic Growth Project, by IRT, Washington, D.C., 1976.

*BOD- Biological Oxygen Demand
**D.S.- Dissolved Solids

This does not mean that such changes do not occur, or are not deliberately introduced. On the contrary, our interviews with various executives of industry suggest that deliberately-introduced changes in various end-products in order to meet environmental and/or occupational safety regulations are frequent and common.[1] Information on most, if not all, of such changes in end-products, however, is considered proprietary and confidential. Therefore no information on these changes is available outside of the particular industry.

There is, however, still another source which provides valuable and relatively comprehensive information on end-product changes undertaken for the purpose of reducing or eliminating hazardous waste generation. This source comprises various reports, studies and other materials pertaining to those end-products that contain extremely hazardous compounds.[2] After their extreme hazard was recognized, these compounds were eliminated and/or modified to less hazardous forms. Examples of such end-products can be readily identified, including various building materials containing asbestos[1] and transformers containing polychlorinated biphenyl (PCB).[2] These are analyzed in detail in subsequent sections of this chapter.

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[1] E.g., Personal Communication with R.O. Kagel, Manager, Environmental Regulatory Activities, Dox Chemical and C.A. Kibler, Senior Staff Engineer, Mobile Oil Corporation, Technical Services Department.

[2] See for example: L.A. Abron-Robinson and E.J. Martin, Treatment Alternatives for Hazardous Waste Management in Nine Industry Groups, by Reer Consultants, Inc. for the Environmental Protection Agency, 1980, I. Gutmanis, et al., Case Studies of Innovation Water Pollution Control Technologies, by Sterling Hobe Corporation for the Environmental Porection Agency, December 1979; A.K. Schwartz, Jr. and R.G. Thompson, An Integrated Power Process Model of Water Use and Waste Water Treatment in Olefins Production, NSF (RANN) GI-34459-1 Technical Report, University of Houston, Texas, January, 1974; I. Gutmanis and S. Keehy, Water Use and Pollution in Textile Industries, for Resources for the Future, Inc., Washington, D.C., 1978 and personal communication with William Richard, Manager, Maleic Anhydride Production, Monsanto Corporation, and with John B. Crowell, Jr., General Counsel for Louisiana-Pacific Corporation.

The subsequent sections of this chapter will present a comprehensive literature review of two types of end-product changes:

- end-product substitutes that resulted in the reduction or elimination of hazardous wastes generated by manufacturing processes; and
- attempts at end-product substitutions which were unsuccessful.

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[1] J.S. Horvitz, "Asbestos and Its Environmental Impact", Environ. Affairs, Vol. 3, No. 2, pp. 145-165, 1974.

[2] Support Document/Draft Voluntary Environmental Impact Statement for Polychlorinated Biphenyls (PBC's) Manufacturing, Processing, Distribution in Commerce and Use Ban Regulations (Section 6(e) of TSCA), Washington, D.C.: Office of Toxic Substances, U.S. Environmental Protection Agency, May 1978.

Conceptual Issues in End-Product Substitution

First, the very concept of end-product substitution, for whatever reason, often is very difficult to isolate from other changes in the technology which were used in the production of the end-product(s) or from changes in raw materials (or inputs) that were utilized in the end-product manufacture. For example, PCB-containing transformers can be substituted with oil-filled transformers (in which case the inputs are substituted), or can be substituted by open-air transformers. In that case, the manufacturing process is changed. Similarly, substitution of cadmium used in electroplating with zinc changes raw materials used and alters the electroplating process.

Another example of this is the substitution for conventional tin plate containers where lead is used as a solder with aluminum or plastic containers. Here, such substitution requires changes in inputs (aluminum or plastic in place of tin plate or lead), as well as changes in the manufacturing process (such as extrusion in place of soldering).

Types of End-Product Substitutes

The above examples raise another issue--that of determining precisely what can or should be considered as end-product substitution rather than substitutions or changes in the manufacturing process and/or technology. It appears that one can distinguish extreme cases of end-product substitution. In one of these extremes, an end-product is substituted for another which has a completely different chemical composition and/or function on the basis of different physical principles. A good example of such end-product substitution is the replacement of chlorofluorocarbons (CFC) as a refrigerant in automotive air conditioners, with air cycle refrigeration systems.

Another example of this would be the substitution for asbestos-cement pipe with cast iron pipe. Still another example is the substitution for urea-formaldehyde insulating foams with such other insulating materials as mineral wool.

At the other extreme, one end-product is substituted for another which retains some of the former end-product's chemical composition or functions in the same manner, although there is some modification. Substitution of PCBs in askarel transformers by appropriate oils or other chemical compounds which retain some of the PCBs' characteristics is an example of this type of end-product substitution. Replacement of mercury in water-based paints with another fungicide is another example of such substitution, as is the substitution of Di-(2-ethylheptyl)-phthalate (DEHP) with some other plasticizer in various plastic products.

On the basis of the literature review, it can be stated that most end-product substitutions fall somewhere between the two extreme cases discussed above.

The literature review also indicates that the end-product which are substituted may be both consumer end-products and industrial end-products.

Further, the end-products may be "true" end-products such as asbestos-cement pipe or rubber cement containing benzene. They may also be intermediate end-products such as capacitors, cadmium-plated electronic components, or asbestos paper.

Purposes of End-Product Substitution

The case studies covered in the literature survey clearly established that most end-product substitutions described were undertaken for the purpose of reducing or eliminating the generation of hazardous substances. The end-product substitutions included in this survey were pre-selected to focus specifically on hazardous waste generation, so this may not present an accurate picture of the reasons behind end-product substitution.

More frequently, end-product substitutions are motivated by such factors as advancing technology (i.e., substitution of mechanical magnetic switching apparatus with microprocessors[1/]); reduced cost of production (substitution of molded plastic parts, such as in t.v. cabinets, for various wood and metal fixtures); end-product substitution because of improved design and consumer acceptance (substitution of paper products--cups, etc.,--with styron and other

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[1/] The advancement in integrated circuits has forced substitution in countless consumer and industrial products in all sectors of the economy.

plastics); substitution for chrome-plated parts in motor vehicles with aluminum stampings); and, finally, there are end-product subsitutions caused by changing public tastes (the significant increase in various convenience foods is an example of this). Note that most of these substitutions are not undertaken for environmental or health purposes. As a matter of fact, the end-product substitutions that are undertaken for the explicit purpose of reducing hazardous waste generation are, most likely, few in number. These few are undertaken for the purpose of reducing or eliminating health risks to the public--not during manufacture of the end-product, but during the use of these products.

In the case of most of the end-product substitutions discussed, the health impact to the users of these end-products has been the principal factor which has promoted substitutions for these end-products, either voluntarily by the firms manufacturing these end-products or because of regulations. Note, however, that in most cases, the manufacture of these end-products generates hazardous wastes which have an adverse impact on the environment, as well as on the employees engaged in the manufacturing operations. However, it is the health risk subsequent to manufacture of the end-products which dominates the attempt to find substitutes for these end-products.

Presence of Hazards in End-Products

This, in turn, suggests that many end-products which generate hazardous wastes during their manufacturing stages embody hazardous substances during their life cycle and even after these products are discarded. All end-products containing mercury, asbestos, PCBs, and cadmium have this common characteristic.

Magnitude of Impacts of End-Product Substitution

An important fact must be remembered when considering the impacts of end-product substitution. The same industry sector or even the same firms which manufacture end-products that generate hazardous wastes are capable of manufacturing substitute end-products. This suggests that such end-product substitution can be achieved with only marginal disruption of the channels of commerce or industry structure.

This is the case because the new end-product can be manufactured, distributed, marketed, repaired, serviced and replaced by using the already established channels. In very general terms, the literature survey indicates that the total impacts of end-product substitution are not large and do not exceed 10 percent of the value of annual shipments from the sector of the economy where the end-product substitution has taken place.[1]

There are a number of caveats to this which need to be stated. First, the number of end-product substitutions covered in the literature review is not sufficiently large to assure that all end-product substitutions undertaken for the purpose of reducing hazardous waste generation will have relatively small total impacts on the industry, the firm(s) and the users of end-products.

Second, as already indicated, most of the end-product substitutions covered in the literature review have the common characteristic that the sector of the economy which manufactured the original end-product also manufactures the substitute end-products. As already discussed, this feasibility significantly reduces the total cost of impacts.

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[1] See subsequent section of this report.

Parties Impacted by End-Product Substitution

Again, in very general terms, the parties that are impacted by end-product substitution include, of course, the sector of manufacturers which produce the end-product to be substituted. The other parties include: the suppliers of raw materials and/or inputs to this manufacturing sector; the sector (if different) which manufactures the substitute end-products; the final users of the end-products (either consumers or industry, or both); and the sector or party responsible for maintenance and repair of the end-product.

There are other parties which may also be impacted by end-product substitution, but probably to a much more limited extent. These include importers of raw materials used by end-product manufacturers and exporters of end-products. Not all of these parties are affected by end-product substitution to the same degree.

Comparative Magnitudes of Impacts Resulting from End-Product Substitution

While any generalization on this issue must be regarded as putative, the literature survey does allow a number of observations on the comparison of impacts resulting from end-product substitution among affected parties. Manufacturers of end-products which are substituted are the parties which are affected the most by such substitution. The magnitude of this impact depends, of course, on the importance of this end-product as compared to the entire line of products or value of shipments from this sector.

For example, as noted elsewhere in this report, the ban on manufacture placed on PCBs had hardly any impact on their sole manufacturer in the U.S., the Monsanto Corporation, because the value of PCB shipments was marginal when compared to the total gross revenues received by Monsanto.

The magnitude of this impact depends also on whether or not the capital stock (producers of durable equipment and structures) used for the manufacture of the end-product that is substituted for can be used for other productive activities. In the case of Monsanto, for example, the production facilities used in the manufacture of PCBs were indeed put to use in production of other chemicals. Conversely, in the case of urea-formaldehyde foam insulation, the equipment used in injecting this foam in wall cavities of structures could not be used for any other purpose, resulting in a loss to the industry.

The magnitude of impact resulting from end-product substitution on the industry that supplies goods and services to the manufacturers of the end-products varies with specific end-products. In the case of PCBs, for example, the PCB manufacturer experienced little, if any, impact from PCBs substitution because most of these chemicals could be readily used in the manufacture of other organics.[1/] Conversely, substitution of cadmium in electroplating will severely impact on cadmium producers, since about one-half of the total cadmium demand is used in electroplating applications. On the other hand, substitution of urea-formaldehyde foam insulation with other types of insulation will impact the urea-formaldehyde manufacturers only marginally, again because of other potential uses of formaldehyde.

A tentative conclusion that can be stated is that if the specific substance or compound that is used in the original end-product has other uses, the impact of substitution is marginal to moderate for the manufacturer of this compound.[2/]

The literature survey suggests that this is the case with most sectors supplying goods and services to the end-product manufacturers that are to be substituted. However, there are exceptions (i.e., cadmium) and it cannot be stated with certainty that impacts on the suppliers of goods and services to the end-product manufacturers will, in most cases, be moderate.

With regard to the impact on the users of end-products, results of literature survey indicate that the magnitude of this impact should not be significant in most cases, although there may be exceptions. The principal reason for this lies in the highly competitive system

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[1/] Such as cyclic phosphoric acid esters, or various phthalates.

[2/] The case studies and interviews with industry executives indicate that outright ban of any one substance for the multi-product firms result in annual gross revenue reductions of less that 5 percent. This, however, may be different for different types of firms, and for single-product firms, may be catastrophic.

of U.S. economy in which replacements for end-products substituted are developed by the industry and offered to the users. For example, in the case of PCBs, various firms in the chemical sector were able to offer a relatively large number of substitutes within a short time period (i.e., three to six months) after Monsanto ceased production of PCBs. Simultaneously, in the case of CFC substitution, a blowing agent for flexible urethane foams, the industry was able to almost immediately respond with a substitute--that of methylene chloride.[1]

The fundamental reasons for the industry's ability to introduce most end-product substitutes without noticeable delay is continuous availability of substitute products for many end-products. While these products may be somewhat inferior to the end-products used, they are often available as immediate substitutes. This, in turn, is the result of industry's continuous research and development efforts to either improve on the existing end-products or to prepare for future substitution.

For example, all major firms which manufacture friction asbestos materials have undertaken significant research and development activities to develop substitutes for asbestos friction materials.[1] Similarly, the chemical industry is developing various chemical compounds to substitute for benzene.

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[1] Note that this chemical is also designated as hazardous waste by the Environmental Protection Agency.

Conversely, the literature review suggests, and surprisingly so, that a party which may be significantly impacted by end-product substitution is the service sector which maintains and operates the substituted end-products. In the case of askarel transformers, for example, the maintenance of non-askarel transformers is apparently more complex and more costly. As noted elsewhere in this report, the maintenance of, say, electronic apparatus manufactured with zinc-electroplated materials in place of cadmium, requires considerably more care and technical knowledge. Thus, the sector which performs maintenance on the substituted end-products may experience considerable impacts from end-product substitution. Note, however, that the above presumes that maintenance work is performed by a sector other than users of the end-products. If this is not the case, these impacts are directed at the user sector.

Other parties which may be impacted by end-product substitution are the exporters and/or importers of the end-products. The literature survey did not find major impacts to these parties resulting from end-product substitution. However, none of the end-products analyzed are significant goods in international trade. Thus, it is not likely that significant impacts would result from end-product substitution to these parties. However, there may be end-products which are significant in foreign trade. In such cases, the impacts from end-product substitution on the exporters may be significant.

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[1] See: Securities and Exchange Commission 10-K Reports for such firms as Bendix Corporation, Abex Corp., H. K. Porter Co., and others. Note, however, that this R&D effort has not as yet resulted in a successful substitution for asbestos.

There is another issue with regard to this which merits a note. This pertains to end-products which play minor roles in the U.S. or which have been substituted domestically some time ago, but are important to other countries. An excellent example of this is DDT. While the United States does not use this pesticide domestically and it has been completely substituted by other pesticides, DDT remains in significant use in the lesser developed countries.

Further, there may be commodities in the international trade which are important componentsof substitutes or substituted end-products. In such cases, the importers and exports of such commodities will be impacted by the end-product substitution. A good example of this is the end-products containing asbestos; since almost 90 percent of all asbestos used in the U.S. is imported from Canada, end-product substitution away from asbestos will have an impact on asbestos importers in the U.S. The same applies to cadmium.

Capacity of Industry

Another issue which needs to be discussed is the impact of end-product substitution on the capacity of the domestic industrial base. The case studies analyzed in the literature review did not indicate any industry capacity problems. On the contrary, each of the end-product substitutions were accomplished without facing capacity shortages. This, however may not be the case with all end-products and/or industry sectors, and some capacity constraints may reduce the pace of the end-product substitution.

Defense Issues

Another issue which needs to be addressed is the impact of end-product substitution on the domestic strategic issues. Principally, we are interested in whether or not end-product substitution may have an impact on the nation's economy related to defense issues.

The literature review suggests that the most likely impact of the end-product substitution on the nation's defense posture would come as a result of the substitute end-product requiring goods and/or sources that are in short supply; as is the case of several substitutes for cadmium. Clearly, such potential impact exists and will depend on specific end-products and specific goods and services.

Ranking Among Several End-Product Substitutes

The literature review suggested that there exist several alternate substitutes for most end-products. The obvious issue that needs to be raised here is whether these alternatives can be ranked in order of acceptability. The literature review suggests that such ranking is not warranted in most, if not all, cases. The reasons for this are as follows.

As a rule, the existing end-products embody optimum characteristics (except for hazardous waste generation) with regard to the manufacturers, users and all other sectors/impacted parties. Substitution of such end-products by another essentially results in the use of an "inferior" end-product, except that this substitute does not generate hazardous waste. However, because of some of the "inferior" characteristics, the substitute end-product may not be readily used in all applications in which the original end-product was used, and/or the substitute end-product requires specific modifications, alterations or changes.

Simply stated, the literature review suggests that there are no one-for-one substitutions of end-products. The availability of alternate substitute end-products, therefore, allows much more feasibility in substituting alternate substitute end-products for various applications. That is, there are no pure alternate substitute end-products. Rather, each alternate possesses unique characteristics not available in other substitute end-products. Several examples should assist in understanding this issue.

In the case of askarel transformers, essentially two substitute transformers are available: open air-cooled transformers and oil-filled transformers. While open air-cooled transformers have many superior characteristics, they cannot be used in certain enclosed areas or in high voltage circuits. Thus, in these applications, oil-filled transformers are used. However, oil-filled transformers are not as safe as askarel-type transformers.

Similarly, asbestos-cement pipe has several alternate substitutes, namely PVC pipe, iron pipe and vitrified clay pipe. However, each of these three substitutes have certain limitations. For example, PVC pipe cannot be manufactured larger than in 12-inch diameters without considerable increase in cost; vitrified clay pipe cannot be used in areas where ground water freezes; and iron pipe has poor durability in alkaline soils. Clearly, these alternate substitutes have their own unique characteristics, as well as limitations, as substitutes for asbestos-cement pipe.

In the case of benzene, four substitutes may be identified: cyclohexane, toluene, xylene, and methylene chloride.1/ Each of these, however, can be substituted for benzene only in specific applications. Other examples can be readily provided, but the above should be sufficient to reject the notion that the existence of alternate end-product substitutes will allow ranking of these alternatives in terms of their acceptance, "goodness" or appropriateness.

Issues Related to User Acceptance of Substitute End-Products

User acceptance of substituted end-products is an important issue. Witness, for example, the public's refusal to purchase

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1/ Note that all of these substitutes generate hazardous waste during manufacture as designated by the Environmental Protection Agency.

unbleached (Kraft) paper products in place of bleached paper, in spite of the promotion by the government and environmental interest groups. However, the literature review suggests that the user acceptance of substituted end-products has far less impact than expected.

The principal reason for this is the fact that the case studies of end-product substitution covered in the literature review are those in which such substitution was either required by various regulations and/or the public was very much aware of the environmental and health hazards caused by the substituted end-products. Thus, the literature survey did not find major issues related to the public's acceptance of the substituted products.

This does not mean that the public's acceptance is not an important factor. Most likely, it is of considerable importance in substitutions which are not related to hazardous waste generation and/or significant environmental and health issues. However, where such issues are present and the public is aware of these, the public's acceptance of substitute end-products is forthcoming. This can be readily seen in the case of aerosol spray (i.e., CFC) substitution by either pump action or solids in various toiletry preparations. As the result of the regulations which have limited CFC use and widespread publicity on the alleged ozone depletion by CFCs, the public's response in this case was that of readily accepting substitutes at a rate faster than predicted by the industry.

In conclusion, the literature survey presented in this chapter clearly outlines a number of issues related to end-product substitution and allows us to make a number of important conclusions, as summarized in Table 2.

Table 2

Principal Issues and Conclusions Related to End-Product Substitution

Issue	Conclusions
Reasons for end-product substitution	The principal reasons for end-product substitution are: •obsolescence of the existing end-product; •reduced manufacturing costs of the substitute end-product; •improved design, life-cycle costs, durability, etc. of the substitute end-product; •changes in consumer tastes; •development of new end-product; Elimination or reduction of hazardous waste generation has also been identified as one of the reasons for end-product substitution, albeit not a principal one.
"Pure" end-product substitution	"Pure" end-product substitution is very difficult to find. As a rule end-product substitution is accompanied by changes in production technologies, raw materials and inputs.
One-for-one end-product substitution	As a rule there are no one-for-one end-product substitutes and the original end-product is substituted by several alternate end-products.
Types of end-product substitution	At one extreme an end-product can be substituted by another with different chemical composition and/or functions or the loss of different physical principles. At another extreme the substitute end-product retains much of the original end-product's chemical composition and/or functions. Most end-product substitutions fall between these two extremes.

Issue (Con't.)	Conclusions (Con't.)
Presence of hazards in end-product	Some end-products which generate hazardous wastes during the manufacturing stages often retain a degree of hazard during their useful life and after disposal. Other end-products generate hazardous wastes only at the time of manufacture and/or specific use, but not after disposal.
Magnitude of impacts of	In very general terms, the impacts of end-product substitution on the sectors of the economy are not substantial, i.e., foregone costs do not exceed 10 percent of the annual value of shipments. The impacts on end-product users are also relatively small because of the presence at any one time of several substitute end-products in the economy. Impacts on the service sector may be more substantial. The impacts on other parties resulting from end-product substitution are not significant, although some end-product substitutions may require the use of scarce resources.
Parties impacted by end-product substitution	The principal parties impacted by end-product substitution are: • manufacturers of the original end-product; • end-product users; • manufacturers of the substitute end-product; and • suppliers of goods and services to the manufacturers and users of end-products. Other parties which may be impacted by end-product substitutions are as follows: • exporters and importers of end-products;

Issue (Con't.)	Conclusions (Con't.)
	• exporters and importers of goods required for the end-product manufacture; and • sectors of the economy which require inputs the same required by substitute end-products.
Type of impacts resulting from end-product substitution	With regard to the end-product manufacturers and sectors supplying goods and services to them: • loss of revenues; • underutilization of production facilities; • additional capital expenditures for new production facilities; • additional input/raw material costs; • additional costs of manufacturing; • additional costs associated with substitute end-product distribution or sales. With regard to the end-product users: • additional end-product costs at the time of purchase or/and life-cycle costs; • additional costs resulting from or possible need to adjust manufacturing and related provisions requiring substitute end-products as inputs; • additional O + M costs related to end-product use. With regard to exporters and/or importers: • loss of revenues with regard to other parties; • increased demand for scarce resources;

Issue (Con't.)	Conclusions (Con't.)
	•increased costs of certain goods and services.
Factors affecting magnitude of impacts	The principal factors that affect the magnitude of impacts resulting from end-product substitution is the extent to which the substitute end-product differs from the original end-product; the smaller the difference the smaller is the impact. In the case of end-product manufacturers, the impacts are significantly reduced if the same firm or sector manufactures both the original as well as the substitute end-product. Conversely, if the substitute end-product is manufactured by another firm and sector, the impacts resulting from the substitution may be significant on both the manufacturer of the original as well as the substitute end-product. Presence of several substitute end-products for the original end-product evidently reduces the impacts on the end-product users and on the manufacturers of the substitute end-products. Finally, the time available for the end-product substitution to take place (either voluntary or prescribed by regulation) has an important effect on the magnitude of impacts. As time progresses, the magnitude of impacts is reduced.
Capacity of industry	Industry capacity does not present problems in most end-product substitutions.
Defense Issues	End-product substitution has an apparently limited impact on defense issues from the point-of-view of manufacturing operations, i.e., industry capacity.

Issue (Con't.)	Conclusions (Con't.)
	Conversely, from the point-of-view of scarce raw materials, some end-product substitutions may have significant impact on defense issues.
Ranking among substitute end-products	Ranking among substitute end-products is conceptually difficult to undertake. This is the case because most original end-products have more than one substitute, each of these best suited for specific application of the original end-product.
User acceptance	User acceptance of substitute end-products have not played an important role. This, however, may be the result of such other factors as health and safety regulations which have focused on end-product substitutes and therefore have educated the public as to the social benefit of each substitution.
Reduction of hazardous waste generation using end-product substitution 1/	Available data for the case studies covered in the reports suggest that an end-product substitution may reduce from 20 to 80 percent of hazardous waste generated. However, this, of course, depends on the specific end-product.
Impact of government regulations 2/	Except for very specific cases Federal government does not mandate or regulate end-product substitution. However, Federal government policies related to R&D funding, environmental and occupational safety regulations, tax and federal procurement policies have significant indirect impact on end-product substitution.

1/ See Chapters II through VII.
2/ See Chapter IX.

The following five chapters of the report present five case studies of successful end-product substitutions that resulted in either reductions or elimination of hazardous wastes. These end-product substitutions were selected jointly by the project staff and Office of Technology Assessment personnel. Table 3 presents the salient characteristics of each case study.

TABLE 3

TENTATIVE CANDIDATES FOR SUCCESSFUL END-PRODUCT SUBSTITUTION CASE STUDIES

End-Product Or Use	Substitutes	Hazardous Waste Reduced or Eliminated
Askarel Transformers	Open air cooled transformers	PCB
Asbestos-Cement pipe	1) Iron 2) PVC 3) Clay	Asbestos
Electroplating	Zinc	Cadmium
Wood piling and Marine piling	1) In-place concrete 2) Driven concrete 3) Steel piling	Creosote
CFC Use in Solvents	1) Methyl chloroform 2) Methylen chloride	CFC's

Table 4 presents the eight-point criteria used in this selection process. Furthermore, the selected end-product substitutions for case studies were also chosen because most, if not all, of these would allow analyses of major impacts resulting from such substitution, as shown in Table 5.

TABLE 4

SELECTION CRITERIA FOR END-PRODUCT SUBSTITUTION

1. Generation of Hazardous Waste
2. Availability of Substitute End-Products
3. Adequate Performance
4. Adequate Supply, Domestic and/or International
5. Comparative Life Cycle Costs
6. Comparative Manufacturing Processes and Costs
7. Engineering Compatability for Users
8. Comparative Reliability

TABLE 5

POSSIBLE IMPACT CATEGORIES RESULTING FROM END-PRODUCT SUBSTITUTION

1. Reduction of hazardous waste;
2. Suppliers of input and/or raw materials for end-products to be substituted;
3. Suppliers of inputs and/or raw materials for substitute end-products;
4. Manufacturers of the end-products which are substituted;
5. Manufacturers of the substitute end-products;
6. Intermediate users of end-products which are substituted; and
7. Final users of end-products which are substituted.

CHAPTER II

POLYCHLORINATED BIPHENYL (PCB) SUBSTITUTION

Polychlorinated biphenyls (PCS) are significant environmental pollutants occuring throughout the biosphere. They pose a substantial risk to the health of humans as well as other animals. A number of adverse effects on living organisms has been demonstrated including bioaccumulation, biomagnification, carcinogenicity mutagenicity, teratogenicity, and fetotoxicity.[1] PCBs are extremely persistent in the environment, circulating among the air, water, and land.

PCBs have been used in the U.S. for over fifty years in a wide variety of applications including transformer cooling liquids, capacitor dielectric fluids, heat transfer and hydraulic liquids, dye carriers in carbonless copy papers, plasticizers in paints, adhesives, fillers, and dust control agents.

Monsanto was the prime U.S. manufacturer of PCBs. Beginning in 1972, Monsanto limited sales of PCB to manufacturers of electrical equipment. In 1977 the firm ceased manufacture of PCBs, and by October of that year had made its last shipment from inventory. Section 6(e)(2)(a) of the Toxic Substances Control Act prohibited the manufacture, processing, distribution in commerce, and use of

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[1] EPA, Support Document/Voluntary Environmental Impact Statement and PCB Manufacturing, Processing, Distribution in Commerce, and Use Ban Regulation: Economic Analysis, Washington, D.C.; Office of Toxic Substances, U.S. Environmental Protection Agency, April 1979, pp. 9-21.

PCBs after January 1, 1978, except in a "totally enclosed manner." This term is defined to mean a manner which ensures that no significant exposure of humans or the environment to PCBs will occur. The use, except servicing, of intact, non-leaking PCB-filled transformers is considered to be one such totally enclosed manner of use.

The EPA has determined that any increase in levels of PCBs in the biosphere is undesirable.[1] Moreover, EPA has determined that PCBs released anywhere into the environment will eventally enter the biosphere.[2] Accordingly, due to the substantial health risks posed by PCBs, the use of substitute end-products has been explored for a variety of products which use PCBs, including transformers.

PCB Transformers

Substitution for PCB filled transformers by other types of transformers[3] and specifically by air-cooled transformers, presents an excellent opportunity to analyze the technical, economic, marketing and management aspects of end-product substitution undertaken in order to reduce environmental contamination during use and

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1/ EPA. Support Document/Voluntary Environmental Impact Statement and PCB Manufacturing, Processing, Distribution in Commerce, and Use Ban Regulation: Economic Analysis, Washington, D.C.; Office of Toxic Substances, U.S. Environmental Protection Agency, April 1979, p38.

2/ EPA, op. cit.

3/ EPA, "Polychlorinated Biphenyls (PCB's), Manufacturing, Processing, Distribution in Commerce and Use Bans," Federal Register, June 7, 1978, pp.24802-24817.

5°

disposal as well as to eliminate hazardous waste generation.[1] Liquid-filled transformers containing a PCB-based liquid known as "askarel" have been used for many years. Where the risk of fire justified the use of a fire resistant fluid, askarel transformers were allowed in such locations as those buildings without requirements for a fireproof vault or fire sprinklers.[2]

Thirteen companies used PCBs in manufacturing these transformers. The companies and plant locations are listed in Table 6. Production of askarel transformers averaged 5,000 units per year in the early 1970's.

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[1] Note that PCB in transformers can also be substituted for other types of liquids. Such substitution, however, represents a process change rather than end-product substitution, and hence is not presented here.

[2] Wood, David (Monsanto): "Chlorinated Biphenyl Dielectrics, Their Utility and Potential Substitutes" in Conference Proceedings, National Conference on Polychlorinated Biphenyls, November 19-21, 1975. Chicago, Illinois. Washington, D.C.: Office of Toxic Substances, U.S. Environmental Protection Agency (Report No. EPA 560/6-75-004), pp. 317-322.

TABLE 6

U.S. TRANSFORMER MANUFACTURERS THAT USED PCBs AFTER 1970

Company Name	Plant Location
Westinghouse Electric Corp.	South Boston, Va. Sharon, Pa.
General Electric Company	Rome, Ga. Pittsfield, Mass.
Research-Cottrel	Finderne, N.J.
Niagara Transformer Co.	Buffalo, N.Y.
Standard Transformer Co.	Warren, Ohio Medford, Oregon
Helena Corp.	Helena, Alabama
Hevi-Duty Electric	Goldsboro, N.C.
Kuhlman Electric Co.	Crystal Springs, Mass.
Electro Engineering Works	San Leandro, Calif.
Envirotech Buell	Lebanon, Pa.
R.E. Uptegraff Mfg. Co.	Scottsdale, Pa.
H.K. Porter	Belmont, Calif. Lynchburg, Va.
Van Tran Electric Co.	Vandalia, Ill. Waco, Texas

SOURCE: Versar, Inc.: PCB Manufacturing Processing, Distribution in Commerce, and Use Ban Regulation:. Economic Impact Analysis, Washington, D.C., 1979.

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The choice among the available alternative non-askarel transformer types during the time period when such transformers were manufactured depended on the requirements of each specific application and the characteristics of the available non-PCB units.[1]

Open Air-Cooled Transformers as Substitutes

One substitute for the askarel type of transformers is the open air-cooled transformer. It substitutes for 100 percent of the PCBs used in the transformers it replaces. In general, the use of open air-cooled transformers is limited to dry, clean locations where the load requirements are fairly even and constant. Such transformers were and are being successfully used in large office buildings where the transformers are located every few floors.

The relative prices of transformers are summarized in Table 7. As the data indicate, air-cooled transformers cost about the same to 10 percent more than askarel units. Based on past sales of 5,000 askarel units per year at an average price of $20,000, a 10 percent cost increase costs users $10,000,000 per year. There is no effect on the demand for transformers for new installations and there may be an increase in the demand for replacement of 1,000 to 2,000 units per year.

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[1] Olmstead, J.: Comments and Recommendations on Makeup Fluid for Askarel Transformers, Waukesha, Wi.: RTE Corporation, November 15, 1977, and, Walsh, E.J.; Voytik, D.E.; Pearce, H.A. (Westinghouse Electric Corporation), Evaluation of Silicone Fluid for Replacement of PCB Coolants in Railway Industry, Final Report, (Report No. DOT-TSC-1294). Cambridge, Ma.: Transportation Systems Center, U.S. DOT, December 1977.

TABLE 7

RELATIVE TRANSFORMER PRICES

Type of Unit	Price: 1000kVA Unit	Price: 2000 kVA Unit
Oil-filled	$15,300	$23,300
PCB	19,900	30,300
Non-PCB askarel	19,000	29,000
RTEmp° 1/	18,400	28,000
Silicone	22,300	34,500
Open air-cooled	20,700	35,000
Sealed gas-cooled	30,600	46,600

SOURCE: MCG Engineers, "Distribution Transformer Status - WTI Profect," Memorandum to U.S. General Services Administration, June 1, 1977, as cited in Versar, 1978, p. 116.

1/ RTEmp° is tradename of air-filled transformers manufactured by Westinghouse.

This additional demand should be easily met since the transformer manufacturing industry has recently been operating at only about 60 percent of capacity.

Versar estimated the following costs associated with PCB substitution: transitional costs, clean-up costs for manufacturers of $100,000 for the year 1978 only, and long-term costs due to higher costs of non-PCB transformers of up to $10 million per year.[1/]

Clearly, the economic impact of the PCB ban in the manufacture of transformers is relatively modest. Because of the availability of substitutes, the technical impact is also not significant, nor does such a ban result in major marketing or management problems. However, beyond these direct manufacturing costs, the ban on PCBs has resulted in very significant additional costs. This came about because in addition to the ban on PCB use, environmental regulations also attempted to dispose of existing PCBs in various end-products. This was accomplished by undertaking costly comprehensive testing of the various end-products for the presence of PCBs.

These costs of decontaminating or scrapping existing equipment and the ban on rebuilding of PCB transformers may be readily referred to as transitional costs. These costs will end when the existing PCBs are finally removed from service. The transitional cost impacts identified in this analysis of the impacts of the PCB Ban Regulation are summarized in Table 8. As the Versar, Inc. data in Table 8 illustrates, the total transition costs associated with the ban of PCB are indeed significant.

The long-term costs resulting from the ban on the use of PCBs are summarized in Table 9.

[1/] Versar, Inc.: PCB Manufacturing Processing, Distribution in Commerce, and Use Ban Regulation: Economic Impact Analysis, Washington, D.C., 1979.

TABLE 8

TRANSITIONAL COST IMPACTS

$ MILLION PER YEAR

Item	1979	Succeeding Years	$ Million Total	Estimated Reliability of Total
PCB Transformers:				
Manufacturer Clean Up Costs	$ .1	0	$ .1	-50% + 500%
Ban on Rebuilding	9.6	*	373 to 749	±50%
Lost Service Time	2.4	*	75	±50%
Locomotive Transformers:				
Retrofill Program to 6% Limit	Complete by Jan. 1, 1982		6.6	±20%
Retrofill Program to 0.1% Limit	Complete by Jan. 1, 1984		5.15	±20%
Analytical Costs	Complete by Jan. 1, 1985		.444	±50%
Oil-Filled Transformers				
Ban on Reclaiming Oil for Resale	3.6 to 5.6	3.2 to 5.6	? No data on duration of impact	-90% to 0%
Cost of Equipping High Efficiency Boiler	No data	0		
Cost of Approved PCB Incineration	0 - 11.1	0 - 11.1	? No data on duration of impact	-90% to 0%
Transformer Service				
Special Storage Areas	**	**	? No data on duration of impact	

* Costs will be incurred over 10 to 30 years, probably increasing slowly for 10 years and then decreasing slowly.

** Information not available in record to make estimate.

TABLE 8 - continued

Item	$ Million Per Year 1979	Succeding Years	$ Million Total	Estimated Reliability of Total
Mining Machines: 1/				
Rebuild Loaders	Complete by Dec. 31, 1981		1.6	±20%
Scrap Continuous Miners	Complete by Dec. 31, 1981		1 to 2.6	±50%
Storage Costs	.01	0	.01	±50%
Exemption of Application	.001	0	.001	±50%
Electromagnets 1/				
Ban on Rebuilding	.1	.1	.96	±20%
Hydraulic Systems: 1/				
Testing	.5 to 1 1.4	(1980-84 total)	1.5 to 2.4	±20%
Retrofill	9.8 to 16.1	1-1.5 (1980 only)	10.8 to 17.6 by 1984	±50%
Disposal of Fluid 50-500 1/ ppm PCBs	1.4	.2 (1980 only)	1.6	±80% + 20%
Marking 1/	.05	0	.05	±50%
Ban on Recycling Fluid	.3 to 1.7	0 to 1.7	.7 to 3.4	-80% + 20%
Heat Transfer Systems: 1/				
Testing	.045 to .06	.135 to .18	.18 to .24	±50%
Retrofill	5.1 to 6.8	9.9 to 13.2 (1980 only)	15 to 20 (by 1980)	±50%
Cost Savings - Disposal of 1/ System			(2.4 to 3.0)	±50%

SOURCE: Versar, Inc., PCB Manufacturing, Processing, Distribution in Commerce, and Use Ban Regulation: Economic Impact Analysis, Washington, D.C., 1979.

1/ These costs represent expenditures required by EPA regulations for PCB elimination in various applications.

TABLE 9

LONG TERM COST IMPACTS

Transformers:	
Increased Cost of Non-PCB Transformers	$0 to $10 million/year
Increased Fire Losses	$0 to $100 million

SOURCE: Versar, Inc.: PCB Manufacturing Processing, Distribution in Commerce, and Use Ban Regulation: Economic Impact Analysis, Washington, D.C., 1979.

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As the data in Table 9 indicate, Versar, Inc. estimates increased costs of non-PCB transformers from $0 to $10 million per year. According to Versar, this wide range of annual cost impact results from several alternatives available.

As shown in Table 7, the PCB transformer prices are $19,900 per 1000kVA unit and $30,300 per 2000kVA unit. Alternatives to PCB transformers range from $15,300 to $30,600 for 1000kVA units and from $23,300 to $46,600 for 2000kVA units. Thus, the long range impacts of PCB transformer substitution will depend on the alternative transformers selected as substitutes for PCB transformers. If, for example, the selected substitutes for PCB transformers are those of oil-filled, non-PCB askarel, or RTEmp type of transformer, the long range cost impact of these substitutions will be zero, because unit prices of all of the above transformers are lower than that of PCB transformers.

Conversely, if the substitute transformers for the PCB type are those of silicone, open air-cooled or sealed gas-cooled, the impact costs of these substitutions may reach $10 million per annum (according to Versar, Inc.) because unit prices costs of these transformers are higher than the corresponding price of PCB transformers. [1] Versar, Inc. estimates increased fire losses from PCB transformer substitution from $0 to $100 million. As already noted, all of the transformers which can be substituted for PCB transformers are less safe than substitution by other types of transformers. To a significant degree, these costs will depend on the type of buildings where the substitute transformers are located, the selection of appropriate transformer type, the appropriate maintenance and inspection procedures for the transformer, and other factors. Thus Versar, Inc. selected for use a relatively wide range of increased fire losses resulting from PCB transformer substitutions.

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[1] Note that the prices of non-PCB transformers are not always higher as compared to PCB transformers as shown in Table 7, versus the cost of substitution estimate of $10 million, therefore assumes utilization of sealed gas-cooled transformers and others which cost more than PCB transformers.

Parties Impacted by Askarel Transformer Substitution With Open Air-Cooled Transformers

Review of the literature[1] on PCB use in transformers, as well as interviews with industry executives, suggest that the principal parties impacted by such substitution are as follows:

1) U.S. manufacturers of PCBs;
2) U.S. importers of PCBs;
3) U.S. exporters of PCBs;
4) U.S. manufacturers of askarel-type transformers;
5) askarel-type transformer service firms; and
6) users of askeral-type transformers.

In addition to these six major parties impacted by this substitution, there are others which may experience certain impacts. These include, for example, manufacturers of raw materials used for the production of PCBs.

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[1] EPA. Support Document/Draft Voluntary Environmental Impact Statement for Polychlorinated Biphenyls (PCBs) Manufacturing, Processing, Distribution in Commerce and Use Ban Regulations (Section 6(e) of TSCA), Washington, D.C.: Office of Toxic Substances, U.S. Environmental Protection Agency, May, 1978, and

Jack Faucett Associates, Inc., Economic Analysis of Proposed Toxic Pollutant Effluent Standards for Polychlorinated Biphenyls: Transformers, Capacitor, and PCB Manufacturers (EPA 230/1-76-008), Washington, D.C.: Office of Water Planning and Standards, U.S. Environmental Protection Agency, October 1976.

However, since these raw materials (i.e., organic compounds) can be used in production of other organic chemicals,[1] replacements of PCBs in transformers with open air-cooled transformers will have very marginal, if any, impact on these firms.

The six major impacted parties essentially cover the entire flow of PCBs through the channel of commerce from PCB manufacturer to importer to users of PCB in an industrial end-product, in this case, utilities, industrial and commercial firms, and railroads.[2] Note that among the parties impacted by this substitution, one is not considered; that is the manufacturers of the substitute product, in this case, the open air-cooled transformer. This is because all open air-cooled transformers are manufactured by the same firms which produce askarel-type transformers.

Type of Impacts Measured

In this case study only direct impacts expressed in monetary terms to the six impacted parties will be measured. There, no doubt, already exist indirect impacts to the other sectors of the economy resulting from the inter-industry relationships. These, however, cannot be estimated because there are no industry input-output tables which separate PCB manufacturers from other organic chemical producers.[3] Note that these may also generate hazardous wastes; therefore there is no net reduction in wastes.

1/ For example, cyclic phosphoric acid esters.

2/ These are discussed in more detail in subsequent sections.

3/ This is in spite of the fact that there is only one major PCB manufacturer. Unfortunately, this firm -- Monsanto -- is the manufacturer of multi-product chemicals, and therefore the input-output method can not be applied to estimate indirect costs.

Note, however, that in addition to monetary direct impacts, other aspects related to this issue are discussed in the following sections.

Impacts on PCB Manufacturers

The only major U.S. manufacturer of PCBs has been Monsanto. An EPA-sponsored study[1] indicates that about one million pounds of PCBs were also manufactured by a small chemical company from 1972 through 1974 for use as a heat transfer liquid.

Monsanto executives estimate total PCB manufacture from 1930 to mid-1977 at about 1.4 billion pounds. On an annual basis, Monsanto estimates PCB sales to askarel transformer manufacturers at 6.7 million pounds. At the 1976 price of PCB of $0.33 per pound, the substitution of askarel-type transformers will result in $2.2 million in foregone sales by Monsanto. The average annual sales for Monsanto in the 1970's was about $4.2 billion; thus, the foregone sales for PCBs represents only 0.05 percent of total Monsanto sales of various chemical products. The impact of the cessation of the manufacture of PCB on Monsanto is obviously negligible. Furthermore, Monsanto has replaced the manufacture of PCBs with production of other types of liquids used in the manufacture of transformers.[2] Finally, because of the characteristics of other organic chemicals and, therefore, there is no loss of capital embodied in Monsanto's production, durable equipment and structures. In summary, the cessation of PCB production on the manufacturers of PCBs has negligible impact. Note, however,

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1/ Versar, Inc., Usage of PCBs in Open and Semi-Closed Systems and the Resulting Losses of PCBs to the Environment, EPA 560/6-77-009 (unpublished Draft Report), September 1, 1976.

2/ Monsanto, SEC 10-K Reports, 1976.

that this may be a unique case due to the relatively small volume of PCBs manufactured compared to the total sales of Monsanto.

Impacts on Importers

PCBs have been imported as components of transformers and capacitors. This source of PCBs does not seem to be significant.

Impacts on Exporters of PCBs

Impacts on exporters of PCBs are not significant.

Impacts on Askarel-Type Transformer Manufacturers

A review of Monsanto's customer list for PCBs in the early 1970's indicated thirteen (13) companies which used PCBs to manufacture askarel transformers. Production of askarel transformers averaged 5000 units per year in the early 1970's. When these companies were contacted by Versar in September, 1977, only one manufacturer was still producing askarel transformers, and it anticipated ceasing production of this type of unit prior to the end of 1977. All of these manufacturers produced oil-filled, open air-cooled and askarel transformers in new applications, provided that the installation is properly engineered. Other substitutes for askarel transformers are also available.

Interviews with this industry's executives indicate no loss of sales due to discontinuance of PCB-type transformers because all of the manufacturers also produce other types of transformers.

Impacts on Askarel-Type Transformer Users

Versar[1] estimates that there are about 140,000 askarel transformers in use. Most are pad-mounted distribution and power transformers located in buildings and electric generating stations, with a substantial number of askarel precipitator transformers being mounted on stacks. Others are used in industrial and railroad applications. The distribution of ownership of these transformers is summarized in Table 10. The average askarel transfer contains 2,500 pounds of PCBs. The total in-service inventory of PCBs in transformers is approximately 300,000,000 pounds. The transformers are owned and maintained by either the utility or the user, depending on the business arrangements made at the time of each installation.

Impacts to the users of substituting PCB transformers with open air-cooled transformers have three components:

1) foregone savings from rebuilding;
2) lost service time; and
3) higher costs of non-askarel-type transformers.

Each of the import components are discussed below.

Foregone Savings from Rebuilding

Assuming that the replacement of an askarel transformer with an open air-type transformer would cost the same as the historical price for an askarel transformer, and that rebuilding would cost 70 percent of the cost of the new transformer, if allowed,[2] the foregone savings from banning rebuilding of askarel transformers would be 30 percent of the cost of the units. Based on an average cost of $20,000 per transformer, foregone savings would be $6,000 per askarel transformer.

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[1] Versar, Inc., Microeconomic Impacts of the Proposed PCB Ban Regulations, prepared for EPA, May 16, 1978.

[2] Based on a consensus of industry estimates obtained by Versar during a telephone

TABLE 10

ESTIMATED NUMBER OF PCB TRANSFORMERS IN SERVICE

Category of User	Number of Units	PCB Content-Pounds
Utilities	42,000	105,000,000
Industrial and Commercial	97,000	191,000,000
Railroad	1,000	4,000,000
	140,000	300,000,000

SOURCE: Versar, Inc., Microeconomic Impacts of the Proposed PCB Ban Regulations, prepared for EPA, May 16, 1978.

Total foregone savings will depend on the proportion of askarel transformers which are scrapped because of non-repairable failures or obsolescence, rather than because of repairable failures. An active market in used askarel transformers existed in the past, but this market has become much less active over the past year because of the provisions of the water pollution control regulations and the OSHA regulations on worker exposure to PCBs which have decreased the attractiveness of these units to prospective purchasers. No data are available on the proportion of askarel transformers that are removed from service prior to failure, and even if historical data were available, it could be misleading because most askarel transformers have not been in service long enough for aging of the insulation to increase the risk of failure of the units. It is likely, based on Versar's estimates rather than on hard data, that one-third to two-thirds of the existing askarel transformers will be retired due to obsolescence prior to failure. The total foregone savings would therefore be $6,000 per unit x 1/3 to 2/3 of the 140,000 units in service, or a total of $280 million to $560 million.

Timing of these foregone savings will depend on the rate at which askarel transformers fail. Present failure rates are low because of the relatively young age of most existing units. An EPA-sponsored study[1/] estimated that approximately 80,000 gallons

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[1/] Versar, Inc., PCBs in the United States: Industrial Use and Environmental Distribution. Springfield, VA: National Technical Information Service (NTIS PB 252 402/3WP), February 1976, p. 114.

of PCBs were used in the repair of askarel transformers in 1976. Assuming an average transformer capacity of 240 gallons of PCBs (300 gallons of "askarel" mixture), this implies that a total of 335 askarel transformers were repaired during that year. This would have to be considered a lower bound estimate of the future impacts of the ban on rebuilding as the rate of failure of askarel transformers is expected to increase as the average age increases. An upper bound estimate might reasonably be based on an average expected remaining service life. Versar, Inc.[1] assumes that one-half of the existing askarel transformers will be removed from service over the next twenty years due to failure or obsolescence. This, in turn, means an average rate of removal from service of 3.4 percent of the 140,000 existing units per annum or 4,760 units. Of these 4,760 units removed annually, one-third to two-thirds (1,587 to 3,173) would have failed. The range of expected failures would therefore be about 335 to 3,173 transformers per year, resulting in annual costs due to foregone savings of $2 million to $19 million per year during the next few years. At an average replacement rate of 4,760 units per year and an average failure ratio of 50 percent, foregone savings would have been $14,280,000 in 1979. This is line (1) of Table 11.

Lost Service Time

Transformers can be rebuilt and returned to service in three to four weeks, compared to a delivery time of 12 to 16 weeks for new

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1/ Versar, Inc., PCBs in the United States: Industrial Use and Environmental Distribution. Springfield, VA; National Technical Information Service (NTIS PB 252 402/3WP), February 1976, p. 116.

units. In the case of many small manufacturing companies, failure of the single transformer which supplies all of the power for the facility can stop all operations until a satisfactory replacement unit is obtained. It is likely that a greater supply of replacement units will become available in response tc a growing demand for fast restoration of service. This increased inventory of spare units will result in increased costs to the companies maintaining the units and increased prices to the users who will be willing to pay more to avoid prolonged loss of electric service. There is no information available as to the costs of renting transformers, but Versar, Inc.[1/] assumes monthly rental of 2 percent of the cost of the unit. This, in turn, means that total costs due to the longer lead times for replacement transformers could increase by the cost of two to three months' rental of an average $20,000 unit or $800 to $1,200 per failed transformer. Based on the assumed number and frequency of askarel transformer failures by Versar, Inc., total costs due to lost service time would be ($800 x 140,000/3.=) $37 million to ($1,200 x 140,000 x 2/3 =) $112 million, and annual costs of ($800 x 335 units =) $268,000 to ($120 x 3,173 units =) $3,800,000 would be expected, with an average cost of (.5 x 4,760 units x $1,000 rental per unit =) $2,380,000. (This is line (2) of Table 11).

[1/] Versar, Inc., PCBs in the United States: Industrial Use and Environmental Distribution. Springfield, VA: National Technical Information Service (NTIS PB 252 402/3WP), February 1976, p. 117.

TABLE 11

COSTS OF SUBSTITUTION OF PCB TRANSFORMERS

Category of Costs	1979	Total Over 20 Years
(1) Foregone Savings From Rebuilding	$2,000,000 to $19,000,000 ($14,280,000 best estimate)	$280 million to $560 million
(2) Lost Service Time	$268,000 to $3,800,000 ($2,380,000 best estimate)	$37 million to $112 million
(3) Increased Loss of Non-PCB Transformers	$0 to $10,000,000	
TOTAL	$2,268,000 to $32,800,000	$317 million to $672 million

SOURCE: Based on Versar, Inc., PCBs in the United States: Industrial Use and Environmental Distribution. Springfield, VA: National Technical Information Service (NTIS PB 252 402/3WP), February 1976, pp. 114-117.

Cost of Substitutes

As already noted, air-cooled transformers will cost about the same to 10 percent more than askarel units. (Table 7). Based on the past sales of 5,000 askarel units per year at an average price of $20,000, a 10 percent cost increase would increase sales and costs to the users by (5,000 x $20,000 x 10% =) $10,000,000 per year. This is line (3) of Table 11. The table shows the total costs of substitution as estimated by the method described above.

Impact on Transformer Service Companies

Maintenance of askarel transformers is usually contracted out to specialized service shops or to the manufacturer of the unit. Major rebuilding is usually performed by the manufacturer. There are approximately 250 small service companies which can perform routine servicing such as gasket replacement and testing of the liquid.

Based on a Versar, Inc.[1] telephone canvass of independent companies which service and repair transformers, and on information obtained during visits to GE and Westinghouse service shops, it is apparent that existing PCB transformers requiring in-shop repair work are being serviced only by the GE and Westinghouse service operations. These two companies have reduced the number of shops presently permitted to service PCB transformers to 15 and 8, respectively, for a total of 23 shops nationwide.[2] These shops are performing the major warranty maintenance for both GE and Westinghouse and for the other transformer manufacturers. There are approximately 250 small electric apparatus service shops which repair transformers.[1] These shops no longer work on askarel transformers because of the risks of major cleanup costs and worker exposure that would be caused by an accidental spill.

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[1] Versar, Inc., PCBs in the United States: Industrial Use and Environmental Distribution. Springfield, VA; National Technical Information Service (NTIS PB 252 402/3WP), February 1976, pp. 114-117.

[2] Versar, Inc., PCB Activity Analysis Papers, Special Report, EPA, OTS, July 11, 1977.

The impact of the substitution would be to end the practice of rebuilding transformers, but there would be no constraints on continued minor field maintenance. The effects would therefore be limited to a decreased demand for the major services performed by the service shops owned by the manufacturers. These same companies would be faced with an increased demand for new transformers. Assuming that manufacturing and rebuilding are equally labor intensive, there would be a change of employment from the service shops to the central manufacturing plants, but no net change in employment.

A rough estimate of the employment effects may be calculated from the total of the transformer rebuilding business. Earlier in this report it was estimated that a minimum of 335 askarel transformers are rebuilt each year at an estimated cost of $14,000 each (70% of an average $20,000 per unit replacement cost). Assuming that one half of the cost was due to direct and indirect labor, the annual payroll resulting from this activity would be equal to (335 x $14,000/2 =) $2,345,000. Assuming an average burdened labor rate of $30,000 per year, this payroll is equivalent to 78 full-time jobs. Since the

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1/ Electrical Apparatus Service Association, Inc., 1977-1978 Yearbook, St. Louis, MO: 1977.

estimates of percent labor and annual wages are rough estimates, the employment impacts might be better stated as ranging from 50 to 100 jobs. It should be noted that increased employment at the manufacturing plants, due to increased demand for new transformers rather than servicing of old ones, will offset these job losses, so any structural unemployment must be considered to be a transitional cost of the regulation.

Hazardous Waste Reductions Through Substitution for PCB-filled Transformers

Given that all PCB-filled transformers will eventually be retired due to failure or obsolescence, any early retirement will not add to the overall flow of hazardous wastes in the long term. Instead, there will be a relative increase over the amounts expected (absent early retirement) in the early years of the expected lifetime of existing askarel transformers, and a concomitant decrease in the later years.

The real reduction in hazardous wastes will be from not producing new askarel transformers. Using the figure mentioned above of an average of 2,500 pounds of PCBs per transformer, and assuming that the early 1970s annual production rate of 5,000 transformers per year would have been maintained, approximately 12,500,000 pounds (2,500 pounds x 5,000 units) of PCBs are eliminated through substitution each year.

The use of air-cooled transformers in place of askarel transformers produces no other hazardous waste (looking only at the coolants used). Thus the substitution is a fully successful one in terms of hazardous waste reduction.

Conclusion

Substitution of PCB-filled transformers will, as demonstrated here, result in the elimination of 12,500,000 pounds of PCBs each year. If air-cooled transformers are used as substitutes, no new hazardous wastes will be generated.

The cost of this reduction in hazardous wastes is not small. As Table 11 shows, the use of non-PCB transformers may result in substantial annual cost increases as high as $10,000,000. However, the annual cost increases resulting from substitution of PCB transformers with other types of transformers depends on the type of transformer which is used as a substitute. While some of the substitute transformers cost less than PCB transformers, others cost more.

Other costs which result from PCB transformer substitution include foregone savings from rebuilding PCB transformers which result in annual costs of $14,280,000 (best estimate) and costs associated with lost service time, estimated at $2,380,000 annually (best estimate).

In total, the annual costs of PCB transformer substitution have been estimated to range from $2,268,000 to $32,800,000. In addition to these costs, the use of non-PCB transformers, which may create certain fire hazards, may result in fire losses estimated as high as $100 million.

These cost estimates underline an important conclusion applicable to this as well as other case studies; namely that there are a number of cost elements resulting from end-product substitution, some of which (such as potential damages resulting from fires caused by use of non-PCB transformers) are very difficult to quantify.

Several other pertinent conclusions may be readily reached from this case study. One of these pertains to the fact that for some end-products, there exists not one but a number of substitute end-products which offer certain flexibility in substitution and perhaps decrease the cost of substitution to the users of the end-products. Furthermore, at least in some cases, these substitute end-products are manufactured by firms which produced the substituted end-products, and therefore the economic impact resulting from end-product substitution for these firms may be reduced.

The producers of goods which are supplied to the manufacturers of the end-products to be substituted (in this case, the chemical firms producing PCBs) may also experience somewhat limited economic impacts resulting from the substitution because the raw materials that were used to manufacture these goods can be used to produce other end-products.[1]

Finally, this case study indicates that there are relatively significant costs associated with those end-product substitutions which have already been put into use in the past. These costs may be higher (in terms of most end-product substitutions) than the substitution costs for new end-products.

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[1] In the case of PCBs, for example, the raw materials can be used to produce Tcyclic phosphoric acid esters. Note, however, that these esters are also hazardous.

CHAPTER III

ASBESTOS SUBSTITUTION

Asbestos is a general term for a group of naturally-occurring hydrated mineral silicates that separate into fibers. Asbestos minerals which have different physical characteristics and are used commercially include: chrysotile, amosite, crocidolite, tremolite asbestos, actinolite asbestos and anthophyllite asbestos. Asbestos is noncombustible which makes it a good thermal and electrical insulator, and it has high tensile strength and moderate to good chemical resistance.[1]

Asbestos is used as a spray- or trowel-applied coating to building surfaces to retard fire, deaden sound or decorate; it is also used in boilers and pipes, and in cement products, plasters, vinyl tile, and miscellaneous products such as lab table tops and ventilation hoods. In the 1950's, one of the most significant advances in the construction industry was the replacement of concrete with asbestos to protect structural steel against fire.[2]

Asbestos pollutants in any form and from all sources are a direct cause of fibrosis and other lung-related deseases.[3] Asbestos

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[1] Levine, R., ed.: Asbestos: an information resource. Washington, D.C.: Department of Health, Education and Welfare, National Institute of Health. DHEW-(NIH)-79-1686, 1978.

[2] Sawyer, R.N., Spooner, C.M.: Sprayed asbestos-containing materials in buildings: a guidance document. Research Triangle Park, N.C.: U.S. Environmental Protection Agency, EPA-450'2-78-014, 1978.

[3] See Acheson, E.D.; Gerdner, M.J.: The ill effects of asbestos upon health. In Advisory Committee on Asbestos. Asbestos. Final Report of the Advisory Committee. Volume 2. Papers commissioned by the Advisory Committee, London: Her Majesty's Stationary Office, 1979; and, National Institute for Occupational Safety and Health. Criteria for a Recommended Standard: Occupational Exposure to Asbestos, 1972; and, National Institute for Occupational Safety and Health. Revised recommended asbestos standard. Washington, D.C.: NIOSH, U.S. Department of Health, Education and Welfare, DHEW (NIOSH) Publication No. 77-169, 1976.

PCB transformers with regard to their potential fire hazard. However, Versar, Inc. or any other source could not quanitfy with more precision the costs of increased fire losses resulting from PCB transformer fibers, even in low concentration, may have carcinogenic potential. Because of health reasons, the Environmental Protection Agency has banned the use of asbestos in several applications. Substitution for asbestos-cement pipe by such other pipes as clay, cast iron, or PCV represents another example of end-product substitution which results in the reduction of hazardous waste generation.

The Asbestos-Cement Pipe Industry

Asbestos-cement pipe, which was developed about 60 years ago, is a durable, inexpensive pipe material extensively used in underground applications. Asbtestos-cement (A-C) pipe is resistant to corrosion, both internally and externally, has high enough strength to withstand pressure pumping, and does not rust and cause discoloration of water.

The two major applications for A-C pipe are water distribution systems and sewer service. Small amounts of A-C pipe are used as telephone and electrical wire conduit and air ducting.

In 1974, more than 200,000 miles of A-C pipe were in use in the U.S.[1] Also in 1974, over 30 percent of all the water distribution pipe sold in the U.S. was made of asbestos-cement. By 1977, roughly a quarter of a million miles of A-C pipe were in service nationwide with approxmiately 10 to 15 thousand miles of new pipe being produced

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[1] Olson, H.L., "Asbestos in Potable-Water Supplies", *J. Amer. Water Works Assn.*, 66 (9), Part I, 515-518, 1974.

U.S. demand for asbestos fiber in A-C pipe has ranged from 122 to 201 thousand tons during the 1967-1979 period; in 1979, about 127 thousand tons were consumed for this purpose. According to the 1977 figures, about 20.0 percent of the total U.S. market for asbestos was consumed in the production of A-C pipes.

The trend in the value of shipments of A-C pipe is shown in Table 12. A growth rate of five to seven percent has been projected for the A-C pipe market in the next three to seven years. Table 13 lists the U.S. manufacturers of A-C pipe and their respective sales in 1975.

TABLE 12

Shipment Value and Quantity of Asbestos-Cement Pipe

SIC Product Code	Product	Total Product Shipments, Including Interplant Transfers							
		1979*		1975		1972		1967	
		Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
32927 73	Asbestos-Cement Products Pipe, conduit, ducts	871.8	227	316.5	197	789.3	143.3	762.1	118.6
32927 75	Pressure pipe								

*Quantity given in 10^3 metric tons
Value given $ million

Source: Bureau of the Census

TABLE 13

MAJOR U.S. MANUFACTURERS OF ASBESTOS-CEMENT PIPE

Manufacturer	Plant Location	Estimated 1975 Sales of Asbestos-Cement Pipe (Millions of Dollars)
Johns-Manville	Manville, NJ	$78.0
	Long Beach, CA	29.0
	Waukegan, IL	15.0
	Denison, TX	14.4
	Green Cove Springs, FL	5.7
	Stockton, CA	--
Certain-Teed Corp.	St. Louis, MO	10.4
	Hillsboro, TX	8.7
	Ambler, PA	7.2
	Santa Clara, CA	4.6
	Riverside, CA	2.2
CAPCO (Cement-Asbestos Products Co., Div. of ASARCO)	Van Buren, AR	8.7
	Ragland, AL	4.3
Flintkote	Ravena, OH[1/]	8.7
	TOTAL	196.9

[1/] Closed 1976

SOURCE: W. M. Meylan, et al., Chemical Market Input/Output Analysis of Selected Chemical Substances to Assess Sources of Environmental Contamination: Task III. Asbestos, for EPA, Washington, D.C., 1978, p. 110.

Roughly 70-75 percent of all the A-C pipe produced is used for water supply with sewer pipe accounting for 20-25 percent of all uses nationwide.[1] In the eastern United States, A-C sewer pipe currently outsells A-C water pipe by approximately three-to-one; however, in most other sections of the country the water pipe outsells the sewer pipe by three-to-one.[2] This is due primarily to factors of climate and topography and the fact that the major water supply lines in the East have been in existence for years; whereas population expansion in other sections of the country has created a demand for new water supply systems. The largest markets for all types of A-C pipe are west of the Mississippi River,[3] as this is the area of the country in which the new population centers are forming.

A-C pipe is produced in sizes ranging from 4 to 32 inches in diameter.[4] The water supply pipe, a pressure pipe, has a somewhat thicker and stronger casing than the sewer pipe. Much of the water supply pipe is pressure-tested before shipping.

A-C Pipe Manufacturing Process Technology and Asbestos Emissions

A description of the manufacturing process is included here to identify the sources from which asbestos is released to the environment from the process. Figure 1 gives the graphic illustration.

1/ Jackson, J., Personal Communication, Director - Asbestos Cement Pipe Producers Association, Arlington, Virginia, 1981.

2/ Lawless, E., Personal Communication, Sales Engineer - A-C Pipe, Certain-Teed Corp., Valley Forge, Pennsylvania, 1981.

3/ Jackson, op. cit.

4/ Daly, A.R., Zupko, A.J., and Hebb, J.L., "Technological Feasibility and Economic Impact of OSHA Proposed Revision of the Asbestos Standard", prepared for the Asbestos Information Association/North America, Washington, D.C., March 29, 1976.

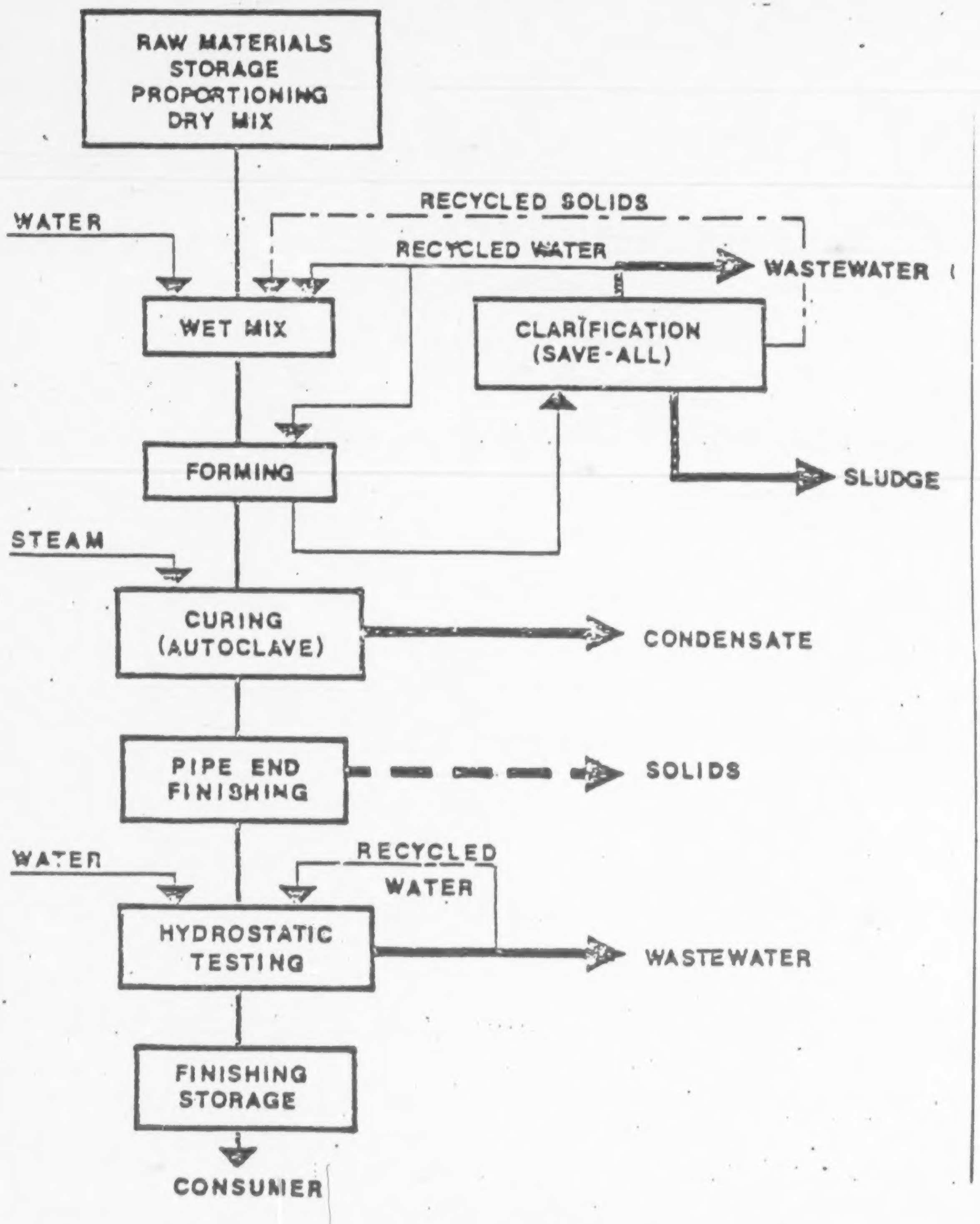
RAW MATERIALS STORAGE PROPORTIONING DRY MIX
WATER
RECYCLED SOLIDS
RECYCLED WATER
WASTEWATER
WET MIX
CLARIFICATION (SAVE-ALL)
FORMING
SLUDGE
STEAM
CURING (AUTOCLAVE)
CONDENSATE
PIPE END FINISHING
SOLIDS
WATER
RECYCLED WATER
HYDROSTATIC TESTING
WASTEWATER
FINISHING STORAGE
CONSUMER

FIGURE 1. ASBESTOS-CEMENT PIPE MANUFACTURING OPERATIONS, WET MECHANICAL PROCESS

SOURCE: Carton, R.J., Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Building, Construction and Paper Segment of the Asbestos Manufacturing Point Source Category for Environmental Protection Agency, 1974.

Asbestos-cement pipe normally contains from 15-125 percent asbestos by weight, usually of the chrysotile variety. In 1976, 83.5 percent of the total amount of asbestos used in A-C pipe was chrysotile, 14.5 percent was crocidolite, and 2 percent was amosite.[1/] Crocidolite is used in sewer pipe to increase production through faster filtering rates. Portland cement content varies from 25 to 70 percent of the total weight. The remaining raw material, from 5 to 35 percent, is finely ground silica. The average content of asbestos-cement pipe, by weight, can be calculated to be about 18 percent.[2/]

The manufacturing steps for the production of A-C pipe may vary slightly from plant to plant; however, the general overall operations are basically the same:

> "After thorough blending of the raw materials, the mixture is transferred to a wet mixer or beater. Underflow solids and water from the save-all are added to form a slurry containing about 97 percent water. After thorough mixing, the slurry is pumped to the cylinder vats for deposition onto one or more

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[1/] Clifton, R.A., "Asbestos", Reprint from the 1978 Bureau of Minerals Yearbook, U.S. Department of the Interior, 1978.

[2/] W.M. Meylan, et al., Chemical Market Input/Output Analysis of Selected Chemical Substances to Access Sources of Environmental Contamination: Task III. Asbestos, for EPA, Washington, D.C., 1978.

> horizontal screen cylinders. The circumferential surface of each cylinder is a fine wire mesh screen that allows water to be removed from the underside of the slurry layer picked up by the cylinder. The resulting layer of asbestos-cement material is usually from 0.02 to 0.10 inch in thickness. The layer from each cylinder is transferred to an endless felt conveyor to build up a slight mat for further processing. A vacuum box removes additional water from the mat prior to its transfer to mandrel or accumulator roll. This winds the mat into sheet or pipe stock of the desired thickness. Pressure rollers bond the mat to the stock already deposited on the mandrel or roll and remove excess water. Pipe sections are removed from the mandrel, air cured, steam cured in an autoclave, and then machined on each end." 1/

It can be noted that, in general, the method used to make A-C pipe is very similar to the methods to make A-C sheet, asbestos paper, and asbestos millboard.

1/ Carton, R.J.; Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Building, Construction and Paper Segment of the Asbestos Manufacturing Point Source Category, for Environmental Protection Agency, 1974.

Asbestos End-Products and Emissions from Manufacture

The quantity of asbestos used in the entire industry and in the manufacture of asbestos-cement pipe is presented in Table 14. For the most part, these figures have been determined by the Bureau of Mines,[1] although some of the end-use categories are considered to overlap.

The estimated environmental disposals and releases of asbestos from all manufacturing and from A-C pipe manufacture are listed in Table 15. These estimates consider the primary manufacturers and most of the secondary manufacturers.

As the data indicate about six percent of the total amount of asbestos consumed by manufacturing is disposed of in landfills or waste piles and of this amount, perhaps one-fifth is in free-fiber or potentially respirable fiber form. In the A-C pipe segment of the industry, about 5 percent of the asbestos consumed goes to landfills or waste piles, of which only one-sixteenth is in free fiber form. Most of this free-fiber asbestos disposed of in landfills is generated by disposal of baghouse collections. Disposal methods of these baghouse collections vary from plant to plant; in some plants, the collections are apparently dumped on a waste pile with no further treatment while other plants may bag and bury these wastes.

The amount of asbestos released to surface waters from manufacturing wastewaters is estimated to be roughly 80 tons annually. More than one-tenth of this amount comes from A-C pipe manufacture. This estimate is, of course, dependent upon the efficiency of clarifying equipment at each individual manufacturing location.

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[1] Clifton, R.A., "Asbestos", Reprint from the 1978 Bureau of Minerals Yearbook, U.S. Department of the Interior, 1978.

TABLE 14

ASBESTOS USAGE IN 1976

	Metric Tons Consumed	Percent of U.S. Asbestos Usage
Total Industry	665,155	100.0
A-C Pipe Manufacture	127,007	19.1

Source: W.M. Meylan, et al., *Chemical Market Input/Output Analysis of Selected Chemical Substances to Assess Sources of Environmental Contamination: Task III. Asbestos*, for EPA, Washington, D.C., 1978.

TABLE 15

ENVIRONMENTAL DISPOSALS AND RELEASES OF ASBESTOS FROM MANUFACTURING
(quantities in metric tons)

	Total Amount to Landfills Or Waste Piles	Amount in Free-Fiber Form to Landfills Or Waste Piles	Amount In Wastewaters To Surface Waters
Total Industry	33,129	6,543	55.6 - 104.2
A-C Pipe Manufacture	10,815	670	10 - 11.4

Source: W.M. Meylan, et al., Chemical Market Input/Output Analysis of Selected Chemical Substances to Assess Sources of Environmental Contamination: Task III. Analysis, for EPA, Washington, D.C., 1978.

Wastewaters from the asbestos-cement product manufacture are treated by methods which vary from plant to plant. Treatment can range from no treatment at all to 100 percent recycling. The most common treatment of wastewaters is sedimentation; some form of sedimentation is applied at nearly all plants in the asbestos industry.[1]

The most important mode of asbestos release to consider is release of free-fibers to the air. From the manufacturing process, emissions from baghouses or other air cleaning devices represent the greatest potential for airborne release of asbestos fibers in free-form.

As noted above, emissions of asbestos during A-C pipe manufacture are significant and while some of their emissions can be captured, most of the engineers working with this industry suggest that it is very difficult to capture all of the asbestos emissions.[2] However, as discussed in the following section, A-C pipe has several substitutes, and asbestos emissions from A-C pipe manufacture could be reduced entirely if these substitutes are used.

1/ W.M. Meyland, et al., Chemical Market Input/Output Analysis of Selected Chemical Substances to Assess Sources of Environmental Contamination: Task III. Asbestos, for EPA, Washington, D.C., 1978.

2/ On this, see:

EPA, Control Technique for Asbestos Air Pollutants, U.S. Environmental Protection Agency, Research Triangle Park, NC, U.S. NTIS PB-222 020, 1973;

EPA, Background Information on National Emission Standards for Hazard Air Pollutants: Proposed Amendments to Standards for Asbestos and Mercury, U.S. Environmental Protection Agency, Research Triangle Park, NC, U.S. NTIS, PB-237 169, 1974;

Margolin, S.V. and Igwe, B.U.N., "Economic Analysis of Effluent Guidelines: The Textile, Friction and Sealing Materials Segment of the Asbestos Manufacturing Industry", U.S. NTIS PB-250 682, 1975; and

McMillan, L., Stout, R., and Willey, B., "Asbestos in Raw and Treated Water: An Electron Microscopy Study", Environ. Sci. Tech., II(4), 390-394, 1977.

A-C pipe is principally used for water distribution and sewer systems. In the first application, it competes primarily with PVC cast iron and steel pipe; in the second application, it competes primarily with vitrified clay, concrete, cast iron and PVC pipe. Speaking in general terms, asbestos-cement is one of the least costly pipe materials. Only locally produced clay and concrete pipe is less expensive in all size ranges. Cast iron and steel are appreciably more expensive than A-C pipe in all size ranges. A-C pipe has the advantage that it does not corrode and increases in strength after being left underground for a period of time. On the other hand, cast iron and steel begin to corrode from the moment they are placed in the ground. They rust, scale, and need cathodic protection. However, cast iron and steel are very old and proven water supply materials and thereby command a healthy percentage of the water supply market.

The newcomer to the market is PVC pipe. For water supply purposes, PVC is estimated to have penetrated into 20 to 30 percent of the total market.1/ One application in which PVC is replacing A-C pipe is in large, rural water mains. In many of these rural applications, the pipe is not required to meet fire-code or AWWA strength standards. This enables a PVC pipe to be produced with a thinner wall and, thereby, a cheaper cost than can be accomplished with a corresponding A-C pipe.

1/ Frey, H.E., "Polyvinly Chloride Resins", Chemical Economics Handbook, Stanford Research Institute, Menlo Park, California, 1976.

Asbestos-cement pipe and PVC are strong market competitors. What is interesting is the fact that the Johns-Manville Corp. and Certain-Teed Corp. are two of the largest manufacturers of both products. Johns-Manville and Certain-Teed control a very sizeable portion of the A-C pipe market. Frey[1] lists Johns-Manville and Certain-Teed as two of the three largest producers of PVC pipe, each having extrusion capacities of 200-300 million pounds per year; Johns-Manville is listed as the largest in the U.S. Johns-Manville has 12 extrusion plants, while Certain-Teed has six. In 1975, an estimated 1,020 million pounds of PVC were consumed in pipe production.

PVC has long been resisted by plumbers' unions and cast iron pipe interests. However, market fundamentals, such as cost, demand, and satisfactory performance, favor continued strong expression of PVC pipe.

> "According to industry observers, leading in the expected continued expansion of PVC pipe and conduit applications will be low-pressure pipe, particularly large diameter water pipe (12 inches and larger), and sewer pipe. Other end uses also expected to continue to grow include telephone conduit and residential hot-water pipe made from post-chlorinated PVC." [2]

Thus, from a technological point of view, the A-C pipe has several substitutes.

The real issues with regard to these substitutes are their comparative costs, the impacts of these costs on various affected parties, and the reluctance by the unions to use one of the principal substitutes to A-C pipe--the PVC pipe. Unlike in the previous case study of askarel transformer substitutes, the A-C pipe manufacturing sector is considerably larger in terms of value of shipments and employment. It is also very closely related and is a large component of the entire asbestos industry.

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[1] Frey, H.E., "Polyvinyl Chloride Resins", Chemical Economics Handbook, Stanford Research Institute, Menlo Park, California, 1976.

[2] Frey, op. cit.

Because of these factors, a brief analysis of the domestic asbestos industry is in order prior to selection of the impacted parties and measure of the impacts brought about by substitution of A-C pipe by the other types of pipe.

Structure of Asbestos Industry

The asbestos industry consists of:

- mining segment;
- milling segment;
- asbestos products manufacturing segment.

The first industry segment to come into contact with the asbestos is, of course, the mining segment. As far as the United States is concerned, however, this predominately occurs in Canada. From 1971 to 1980, between 80 and 85 percent of the asbestos consumed domestically was imported, and of the imported asbestos, nearly 96 percent originated in Canada. Comparatively small tonnages were imported from Africa but these are more important than would appear on a tonnage basis because they consist largely of special kinds and qualities unobtainable elsewhere.

With regard to domestic mining, asbestos is mined in only a few states although mineral deposits which sometimes contain asbestos are located throughout the United States. In order of decreasing annual production, the mining states are California, Vermont, Arizona, and North Carolina. All of the mines produce chrysotile asbestos with the exception of the Powhattan mine in North Carolina which produces anthrophyllite asbestos (this mine has been inactive since 1973).

Based upon the combined data of Harwood and Blasznak,[1/] Clifton, and Asbestos Magazine, we estimate that at the present time about 55 to 65 percent of the asbestos mined in the United States is mined in California; 35 to 45 percent comes from Vermont; and less than 5 percent is mined in Arizona and North Carolina. Until recent mine closings and sales altered the California production, California has accounted for nearly 70 percent of the domestic fiber. Potential mining has been discussed for Alamore, Texas (tremolite asbestos); Sonora, California; and the Yukon region of Alaska.

In summary, U.S. asbestos mine production is small and declining.

The milling segment of the industry is very closely connected to the mining segment because mills are usually located in close geographical proximity to the mines and, in general, the mines and mills are owned and operated by the same parent corporation.

The interesting relationship is, however, the relationship between the mining segment of the industry and the primary industries, the product manufacturers who initially fabricate asbestos products.

[1/] Harwood, C.F. and Blasznak, T.P., "Characterization and Control of Asbestos Emissions from Open Sources", ITT Research Institute, Setp. 1974, U.S. National Technology Information Service (NTIS), PB 238 925, 1974.

Four corporations (Johns-Manville, Raybestos-Manhattan, Jim Walter, and ASARCO) not only control large mining interests in Canada, but also control nearly 35 percent of the American asbestos products market.

According to the 1977 U.S. Census of Manufacturers, 111 firms operating 147 establishments were involved in asbestos products manufacturing (SIC 3292; this does not include asbestos paper-making establishments). When the asbestos papermakers are included, it is estimated that approximately 185 firms are presently engaged in asbestos products manufacture.[1/] In evaluating the asbestos products manufacturing industry, it is possible to arrive at the conclusion that the industry is dominated by several giant firms. The six largest firms control over 50 percent of the market. It should also be noted that the larger asbestos-based manufacturing firms have generally diversified into other product lines. Table 16 shows the percentage of some major manufacturers' product lines that are related to asbestos.

Asbestos products manufacturing plants are characterized by a high degree of specialization. The typical plant (especially of the minor manufacturers) is apt to be a single-product operation whose product is geared to service a specific industry. Table 18 lists the general statistics for establishment specialization in 1972 and 1977. In Table 17, the measures of plant specialization are shown as: (1) industry specialization - the ratio of primary products shipments to total product shipments (primary plus secondary); and (2) product class specialization - the ratio of the largest primary product class shipments to total product shipments (primary plus secondary) for the establishment.

1/ W.M. Meylan, et al., Chemical Market Input/Output Analysis of Selected Chemical Substances to Assess Sources of Environmental Contamination: Task III. Asbestos, for EPA, Washington, D.C., 1978.

TABLE 16

ASBESTOS-BASED ACTIVITY OF SOME MAJOR ASBESTOS-MANUFACTURING COMPANIES

Company	Estimated Annual Sales ($ millions)	Percent of Product Line Related to Asbestos
American Biltrite Rubber Co.	161	5
The Flintkote Co.	441	12
GAF Corp.		5
Johns-Manville Corp.	800	30
National Gypsum Co.	519	5
Jim Walter Corp.	880	8

SOURCE: W. M. Meylan, op. cit., Chemical Market Input/Output Analysis of Selected Chemical Substances to Assess Sources of Environmental Contamination: Task III. Asbestos, for EPA, Washington, D.C., 1978.

TABLE 17

INDUSTRY SPECIALIZATION AND PRIMARY PRODUCT CLASS SPECIALIZATION FOR ASBESTOS-CEMENT PRODUCT PRODUCING ESTABLISHMENTS: 1972 and 1977

	Number of Establishments		Number of Establishments With 75% or More Specialization	
	1972	1977	1972	1977
Asbestos and Asbestos-Cement Products	55	57	42	41

Source: Bureau of the Census.

A survey of selected facilities shows that nearly all the large plants employing in excess of 100 workers belong to the major firms within the industry. Such facilities also often generate relatively minor proportions of non-asbestos products.

As already noted with regard to A-C pipe manufacturers, these firms are the second largest consumers of asbestos products in the United States. See Table 13. Manufacturers listed in Table 13 account for more than 95 percent of the total A-C pipe production in the U.S. and this table clearly shows Johns-Manville as the industry leader in the production and sales of this product. Finally, Table 18 projects demand for A-C pipe to the year 2000. As the projections indicate, the asbestos demand for A-C pipe is expected to reach 279 thousand metric tons in 2000 as compared to the 1975 demand of 155 thousand metric tons. Note, however, that these demand projections assume no substitution of A-C pipe.

In summary, the asbestos product manufacturing sector in the United States is relatively large and is increasing and is dominated by a few large firms. The unique aspect of this industry is that U.S. asbestos mines can supply only about 10 percent of the total domestic demand and, therefore, U.S. manufacturers must rely on imports for their asbestos requirements. Note, however, that a large proportion of foreign (i.e., Canadian) asbestos mines are owned by U.S. manufacturing firms.

Parties Impacted by A-C Pipe Substitution With Other Materials

The analysis of the asbestos product manufacturing sector, presented above, allows selection of parties which are impacted by A-C pipe substitution with other materials. This analysis clearly indicates that domestic asbestos mines and milling operations will be only marginally, if at all, affected by substitution of A-C pipe

TABLE 18

PROJECTIONS AND FORECASTS FOR U.S. ASBESTOS DEMAND FOR A-C PIPE MANUFACTURE, 1975 and 2000

(Thousand Metric Tons)

		2000			
		Contingency Forecasts for United States			
			Forecast Range		
End Use	1975	Forecast Base	Low	High	Probable
Asbestos cement pipe	155	248	274	535	279
Asbestos, Total	618	---	1042	2032	1054

SOURCE: Clifton, op. cit.

The domestic asbestos mines and associated mills, as noted above, are supplying only a small fraction of domestic asbestos demand and any curtailment in this demand is not likely to have an impact on domestic mines. Likewise, because of the weight and volume of A-C pipes, there are no exports of these products and, therefore, there are no impacts on exporters.

With regard to asbestos imports, as already indicated, these supply about 90 percent of total domestic demand. However, as indicated above, the importers are the U.S.-based manufacturers of asbestos products, rather than independant import firms or trading companies.

In summary, the following four parties most likely will be impacted from A-C pipe substitution with other materials:

1) Manufacturers of A-C pipe (also in their role as importers of asbestos);
2) Users of A-C pipe, i.e., local governments/communities;
3) Manufacturers of clay pipe; and
4) Manufacturers of iron pipe.

As in the case of askarel transformers, the parties impacted by the substitution of A-C pipe with other materials represent both manufacturers and users of A-C pipe.

Note, however, that in this case, the impacted parties also include manufacturers of two out of three of the substitute products, i.e., clay and iron pipe.

However, in the case of PVC pipe, which also represents a clear substitute for A-C pipe, the two principal firms, i.e., Johns-Manville Corporation and Certain-Teed Corporation (these two firms manufacture over 90 percent of all A-C pipe sales in the United

States), are also the principal manufacturers of PVC pipe. Industry sources estimate that these two firms produce over 90 percent of PVC pipes' total shipments in the U.S. also. Therefore, substitution of A-C pipe with PVC pipe will have only marginal impacts on the large A-C pipe manufacturers.

Impact on A-C Pipe Manufacturers

Substitution of A-C pipe with PVC, iron and clay pipes will certainly have an impact on those A-C pipe manufacturers which do not provide PVC pipe. The magnitude of this impact will, of course, depend on the proportion of the substitution.

During the last decade, PVC pipe, according to industry sources, has been substituted for A-C pipe at a rate of about 2 or 3 percent per annum. This substitution significantly reduced labor costs in installation. Therefore, reduced overall costs of the PVC pipes installed resulted in spite of the fact that PVC pipe costs about 100 percent more, as is discussed in the following section.

Another reason for the increased use of PVC pipe is certain regulations and/or specifications by local authorities against the use of A/C pipe in certain applications, principally in water supply systems. However, these local regulations vary considerably from one locality to another, without any distinct pattern. Note, also, that some locations prohibit the use of PVC pipes. Finally, some unions in various locations have refused to install A-C pipe, allegedly because of public health considerations, while other unions in other locations have prohibited their members from installing PVC pipe. Clearly, the trends in the substitution of A-C pipe by PVC pipe can not be determined with any certainty. Furthermore, as discussed in the following section, the same type of uncertainty exists when A-C pipe is substituted with iron or clay pipes.

To put it simply, the various factors discussed above preclude projection as to the rate at which A-C pipe will be substituted with other materials. In light of this and also in order to indicate the maximum possible impacts to the A-C pipe manufacturers resulting from A-C pipe substitution, we will assume that all A-C pipe is substituted by other materials. On the basis of industry sources which have refused to be identified and have emphasized that their estimate represents only an approximation, based on historical trends, there are no more definitive information available on this subject. The following types of substitution may occur. About 70 percent of currently manufactured A-C pipe will be substituted with PVC pipe. About 20 percent of currently manufactured A-C pipe will be substituted by cast iron pipe. The remaining 10 percent will be substituted by clay pipes. Note, however, that these figures are only rough estimates.

Assuming the annual average value of A-C pipe shipments is $200 million, 1/ 70 percent of this, or $140 million, will be replaced by PVC pipe. Since PVC pipe is manufactured by the same firms which produce A-C pipe, there is no loss to this sector of industry. As a matter of fact, since PVC pipe costs about twice the price of A-C pipe, these manufacturers will experience a significant net gain of about $140 million. About $40 million

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1/ There are no published data on this--the $200 million represents industry estimates.

of A-C pipes will be substituted by cast iron pipes and another $20 million by clay pipes, for a total of $60 million. This $60 million figure essentially represents a loss in the value of shipments to the A-C pipe manufacturers, leaving them with a net gain of about $80 million ($140 million minus $60 million).

Impact on Iron Pipe Manufacturers

As already noted, about $40 million worth of A-C pipe will be susbtituted by iron pipe. Given the higher unit cost of iron pipe,[1] about $100 million worth of iron pipe will have to be manufactured in order to replace the $40 million worth of A-C pipe. This $100 million represents a gain to iron pipe manufacturers of additional sales of iron pipe resulting from the A-C pipe subsitution.

Industry sources indicate that manufacturers of iron pipe have underutilized manufacturing capacity and, therefore, additional demand of such pipe valued at $100 million could be easily met by this sector.

Impacts on Clay Pipe Manufacturers

The cost of clay pipe is essentially the same as A-C pipe, although clay pipe becomes more expensive in the longer sizes.[2] Substitution of $20 million worth of A-C pipe with clay pipe results in additional sales of $20 million to clay pipe manufacturers.

Clay pipe manufacturers are typically relatively small, local firms with significant underutilization of their manufacturing capacity.

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[1] See Table 19.

[2] See Table 20.

Additional demand for clay pipe valued at $20 million per annum will be easily met by this sector.

Impacts on A-C Pipe Users

The principal users of A-C pipes are various local governments representing communities which utilize A-C pipe for water supply systems and other installations. Unlike the case of the previous impacted parties, where the impacts from A-C pipe substitutions have been marginal, users of A-C pipes will experience more significant impacts from such substitutions. These imports will result from both increased cost of substituted pipe as well as increased installation (except in the case of PVC pipe).

This can be clearly seen from data shown in Tables 19,20 21, 22 and 23.

When total costs are compared, Table 19, the A-C pipe is the cheapest, followed by vitrified clay. Cast iron pipe is more than four times as expensive as A-C pipe.

When labor costs (Table 21) and output, i.e., linear feet of pipe installed per day (Table 22), are considered, PVC pipe is the most attractive, followed by A-C pipe. Stated another way, vitrified clay and cast iron pipe can be installed at less than one-half the rate of PVC and A-C pipes.

Furthermore, as indicated in a recent study,[1/] the pH of soils often dictates the type of pipe required as shown in Table 24. Clearly,

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[1/] Byrd, Tallamy, MacDonald and Lewis, Kentucky Culvert Study, Falls Church, Virginia, 1979.

substitution of A-C pipe by cast iron or vitrified clay pipes will add significant costs to the users. If, however, PVC pipe can be used the additional cost resulting from substitution will be marginal.

TABLE 19

TOTAL COST COMPARISON FOR VARIOUS PIPES, 1980
(per linear foot of installed pipe)

Size/ Diameter	A-C Pipe	Vitrified Clay	PVC	Cast Iron
8"	$ 3.04	$ 4.41	$ 5.08	$13.53
10"	4.65	6.36	7.87	17.52
12"	5.03	7.89	10.93	24.90
14"	7.46	14.32		
15"	8.38	16.32	20.42	
18"	12.85	20.19		
20"	15.80	27.28		
24"	21.48	33.65		
20"	32.81	60.23		

Source: Dodge Guide to Public Works and Heavy Construction Costs, 1981.

TABLE 20

MATERIALS COST COMPARISON FOR VARIOUS PIPES, 1981
(per linear foot)

Size/ Diameter	A-C Pipe	Vitrified Clay	PVC	Cast Iron
8"	$ 2.35	$ 2.93	$ 4.57	$ 8.09
10"	3.96	4.70	7.33	10.72
12"	4.21	6.17	10.36	16.51
14"	6.97	11.21		
15"	7.32	11.83	19.81	
18"	10.42	14.99		
20"	12.94	21.10		
24"	18.21	25.59		
30"	28.23	50.36		

Source: Dodge Guide to Public Works and Heavy Construction Costs, 1981.

TABLE 21

LABOR COST COMPARISON FOR VARIOUS PIPES, 1981
(per linear foot of installed pipe)

Size/ Diameter	A-C Pipe	Vitrified Clay	PVC	Cast Iron
8"	$ 0.69	$ 1.48	$ 0.51	$ 2.86
10"	0.69	1.66	0.54	3.58
12"	0.82	1.72	0.57	4.21
14"	0.89	2.54		
15"	1.06	2.56	0.61	
18"	1.40	2.96		
20"	1.88	4.02		
30"	2.64	5.62		

Source: Dodge Guide to Public Works and Heavy Construction Costs, 1981.

TABLE 22

EQUIPMENT COST COMPARISON FOR VARIOUS PIPES, 1981
(per linear foot of installed pipe)

Size/ Diameter	A-C Pipe	Vitrified Clay	PVC	Cast Iron
8"				$ 2.58
10"				3.22
12"				4.18
14"				
15"		$ 1.93		
18"	$ 1.03	2.24		
20"	1.21	2.66		
24"	1.39	3.04		
30"	1.94	4.25		

Source: Dodge Guide to Public Works and Heavy Construction Costs, 1981.

TABLE 23

OUTPUT COMPARISON FOR VARIOUS PIPES, 1980
(linear feet of installed pipe per day)

Size/ Diameter	A-C Pipe	Vitrified Clay	PVC	Cast Iron
8"	770'	290'	850'	320'
10"	770'	260'	800'	256'
12"	650'	250'	750'	200'
14"	600'	230'		
15"	500'	220'		
18"	330'	190'		
20"	280'	160'		
24"	245'	140'		
30"	175'	100'		

Source: Dodge Guide to Public Works and Heavy Construction Costs, 1981.

TABLE 24

TYPE OF PIPE MATERIAL USED BY pH OF DRAINAGE WATER

	pH Ranges					
Type of Pipe Material	Ohio	Pennsylvania	Virginia	W. Va.	Other State Practices	BIHL Proposal for Kentucky
Plain Galvanized Corrugated Steel Pipe	*	5.0-8.0	*	*		Greater than 6.0
Reinforced Concrete Pipe	4.0-9.5 Type II cement in high acid areas	3.5 or above	All	N/A	High acid to 8.0, Alabama Acid Area Kansas	Greater than 4.0
Aluminum Corrugated Pipe	*	5.0-8.0	4.0-9.0	*	4.0-8.0 Indiana 6.5-8.5 Alabama 4.5-8.0 New Jersey	Greater than 6.0
Bituminous Coated and Paved Corrugated Galvanized Steel Pipe	4.0-9.5	5.0 or less greater than 8.0	4.0-9.0	N/A	Acid areas Indiana 4.5-8.5 Alabama	Greater than 4.0 thru 6.0
Bituminous Coated and Paved Aluminum Corrugated Pipe	*	5.0 or less	4.0-9.0	*	4.5-6.5 Alabama	Greater than 4.0 thru 6.0
Asbestos Bonded Bituminous Coated and Paved Galvanized Corrugated Steel Pipe	4.0 or less 9.5 or greater	*	*	N/A	Less than 5.0 Greater than 9.0 Washington	4.0 or less
Reinforced Concrete Pipe with Extra Protection	*	*	*	*		4.0 or less
Vitrified Clay Extra Strength Pipe	All conditions	3.5 or less	*	4.5 or less 8.3 or above	Acid conditions. Indiana Less than 4.5	4.0 or less
Stainless Steel Corrugated Pipe	4.0 or less 9.5 or above	3.5 or less	4.0-9.0	4.5 or less 8.3 or above		4.0 or less
Vitrified Clay Lined Reinforced Concrete Pipe	4.0 or less 9.5 or above	3.5 or less	*	4.5 or less 8.3 or above		4.0 or less
Cast Iron Pipe	*	*	*	N/A		4.0 or less
Coal Tar Epoxy Lined Reinforced Concrete Pipe	4.0 or less 9.5 or above	3.5 or less	*	*		

*State specifications do not address this type of pipe

N/A-Information not available

Source: Byrd, et al. op cit.

Reduction of Asbestos Emissions Resulting From Substitution

Tracing of the various paths through which asbestos enters our environment is complicated by the popularity of this material (3,000 uses according to the Asbestos Information Association of North America). Still, despite the gathering of specific data on asbestos emissions over all the years since asbestos was found to cause cancer in industrial workers[1] and to prevade the urban environment,[2] there is still controversy over the amounts and even the sources of contamination.

Nevertheless, annual asbestos emissions from all[3] manufacturing operations have been estimated with some precision. These are as follows:

Collected in Baghouses	-	8,675 metric tons
Landfills	-	33,060 metric tons
Wastewater to Surface Water	-	55 to 104 metric tons
TOTAL	-	41,790 to 41,839 metric tons

As indicated in Table 25, the total asbestos disposal from A-C pipe manufacturing activity is about 21,000 metric tons, including both solid and liquid wastes. This represents almost 29 percent of the total asbestos emissions from all asbestos manufacturing. Assuming that all A-C pipe would be substituted by other materials, a very significant portion of the total asbestos waste generation would be eliminated.

1/ R. Doll, "Mortality from Lung Cancer in Asbestos Works", Brit. J. Ind. Med., Vol. 12, p. 18 (1955).

2/ W. J. Nicholson, A. N. Rohl, & E.F. Ferrand, "Asbestos Air Pollution in New York City", in Proc. 2nd International Clean Air Congress, H.M. Englund & W.T. Berry, eds., Academic Press, New York, pp. 136-139 (1971).

3/ Note that these emissions are from all asbestos manufacturing operations. Table 16 indicates asbestos emissions from A-C pipe manufacturing.

Generation of Other Hazardous Wastes Resulting from Substitution

While substitution for A-C pipe by other types of pipe will reduce the generation of asbestos waste, it may result in the generation of other types of hazardous wastes. For example, in the manufacture of PVC pipe vinyl chloride gas is given off, in the manufacture of iron pipe phenols, cyanides, and other wastes are given off, and in the manufacture of clay pipe, fluorides may be given off. The specifics of the hazardous waste generation of these three types of pipe are discussed in turn in the following paragraphs.

PVC Pipe.

In the manufacture of PVC pipe, vinyl chloride monomers are first processed into polymers which are then formed into the desired product. Approximately four percent of the vinyl chloride which enters this production process is lost in manufacture.[1] It is released as vinyl chloride gas and as particulates. Additionally, so-called "heavy ends" from the distillation of vinyl chloride are produced. This is a hazardous waste.

The vinyl chloride gas is regarded primarily as an occupational hazard rather than an environmental hazard. This is because of vinyl chloride's low boiling point and insolubility in water which make it tend to migrate in the air rather than in water or the soil. When exposed to the sun, vinyl chloride gas is destroyed, having a half-life of about two days.[2] Emissions get into the air via stacks, vents, unloading facilities, and similar sources. The substance is a known carcinogen.

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[1] Sittig, M., Vinyl Chloride and PVC Manufacture, Park Ridge, New Jersey: Noyes Data Corporation, 1978, p. 196.

[2] This results in some chlorine emissions.

PVC pipe manufacture may also be a source of water pollution. Monomers, polymers, organic and inorganic salts, organic acids, resin and rubber fine solids, dispersants, wetting agents, and catylists may all be released into water during manufacture. Depending on the nature of manufacturing process, these materials may include hazardous wastes.

Clay Pipe

Clay pipe is manufactured from basic ores which are processed through separation and conditioning by screening, floating, grinding, blending, and drying. The resulting raw materials are subsequently heated and formed into the end-product.

This process gives off a variety of waste products, as follows:

- By-products - these are impurities in the clay ores, removed during the purification process;
- Particulates - these are dust-sized clay particles, given off during storage, handling, grinding, screening, and cutting operations;
- NOx - these gases are given off during the heating of the raw materials; and
- Fluoride - this is also given off when the raw materials are heated, but in small quantities.

Only very small quantity of hazardous wastes are produced in the manufacture of clay pipes relative to the amount produced by the use of A-C pipes.

Furthermore, most of the waste products from clay pipe manufacture can be easily controlled. All of the waterborne wastes can be controlled by simple sedimentation. Point source airborne wastes are controlled using filters and scrubbers. There are two exceptions to the above. NOx wastes are very difficult to control, except by lowering combustion temperatures. Furthermore, clay pipe manufacture results in significant particulate generation which is difficult to control in older, vintage clay pipe manufacturing technologies. More advanced clay pipe manufacturing processes have built-in particulate abatement systems.

Iron Pipe

Iron pipe is produced via the well-known processes of smelting to refine the iron ore and then casting the resultant iron into the appropriate shapes. These processes produce a long list of hazardous wastes including phenols, cyanides, chlorides, chromium, and cadmium.1/

Net Hazardous Waste Reduction

Obviously, any decrease in the use of A-C pipe will reduce the amount of hazardous waste released by the manufacture, use, and disposal of A-C pipe. To be specific, complete substitution of A-C pipe with other types of pipes would reduce annual asbestos emissions into the environment by 10,815 metric tons.

As in the previous case study, A-C pipe has several possible substitutes, e.g., PVC pipe, iron pipe and clay pipe. Unlike in

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1/ Szekely, J., ed., The Steel Industry and the Environment, New York: Marcel Dekker, Inc., 1973.

the previous case study where the substitute end-product unit costs were clustered in terms of price, in this case the alternate end-products have significant price differences. Furthermore, there also exists significant cost differential among the various pipes resulting from differences in labor and equipment costs required for installation. As the result of these differences, the total costs for various alternative pipes varies considerably. For example, in the case of 12-inch pipe, the total costs per linear foot of installed pipe varies from $5.03 for A-C pipe to $24.90 for cast iron pipe.

Furthermore, the specific type of substitute pipe that can be used in place of A-C pipe depends on a host of factors including the specific use of the pipe, the size of pipe required, local climatic and soil conditions, and local ordinances. The cost of A-C pipe as well as of substitute pipes increases at an accelerated rate as the diameter of the pipe is increased.

These increases are not even among all types of pipe. For example, whereas 8-inch A-C pipe and vitrified clay pipe have close unit costs ($3.04 and $4.41), 20-inch vitrified clay pipe costs almost twice as much as A-C pipe, i.e., $60.23 as compared to $32.81.

In light of these wide cost variations, it is not possible to estimate the costs of A-C pipe substitution by other types of pipe with any validity. It is clear from unit costs however (Tables 19 through 23) that all substitute pipes will cost more.

Another conclusion that can be reached from this case study is that all of the substitutes for A-C pipe generate certain hazardous wastes, albeit different types of wastes and/or to a lesser degree, during the manufacturing phases as well as in use and at the time of disposal.

Thus, any increase in the use of a substitute pipe will increase the amount of hazardous wastes resulting from its manufacture, use and disposal. Thus, the issue of end-product substitution as a means of hazardous waste reduction becomes one of net hazardous waste reduction in which one type of hazardous waste is eliminated but replaced by another in relatively smaller quantities.

As the preceeding descriptions have shown, clay pipe represents a substitute for A-C pipe that produces the least amount of hazardous wastes so it is the most promising substitute from the standpoint of hazardous waste reduction. Moreover, as the total cost comparison shows (Table 19), it is the least expensive in all sizes of the three substitutes considered here.

Chapter IV

SUBSTITUTIONS FOR CADMIUM IN ELECTROPLATING

Cadmium even in trace amounts has adverse health impacts, and use of cadmium has been reduced in all applications because epidemiological studies indicate a relationship between several forms of cancer and occupational exposure to cadmium oxide dust and fumes.[1] Replacing cadmium with zinc in electroplating applications represents another end-product change undertaken for the purpose of eliminating hazardous waste generation.

Cadmium is produced as a by-product of zinc refining. In 1978, the total U.S. consumption of cadmium was about 6300 metric tons, at a cost of about $85.00 per metric ton. About one-third was imported. By 1985, demand is expected to reach 9600 metric tons. Of the total use in 1978, about half went to electroplating, with the remainder going to plastic stabilization, pigments, batteries, and a variety of other uses.

The identifiable releases of cadmium to the environment were estimated at a total of 1800 metric tons for 1976. Of this, about 20 percent was from zinc mining and smelting via air, water and tailings; fifty percent was from such indirect sources as fossil fuel combustion, fertilizer use, and disposal of sewage sludge; and thirty percent was from industrial uses, such as resmelting of cadmium-plated scrap, incineration of plastics containing Cd and electroplating (Table 25).

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[1] See: Chave, S., et al., "Zinc and Cadmium in Normal Human Embryos and Fetuses"; Archive Environmental Health, 26:237 (1973);

Cadmium and the Environment: Toxicity, Economy, Control; Paris, Environment Directorate, Organization for Economic Cooperation and Development (1975); and

Ferm, V.H., "Development Malformations Induced by Cadmium"; Biol. Neonate, 19:101 (1971

TABLE 25

IDENTIFIABLE RELEASES OF CADMIUM YEARLY AVERAGE

Source	Magnitude (in metric tons)	Percent	Carrier
Zinc Smelting	360	20	air, water, solid waste (tailings)
Fossil fuel combustion, fertilizer use, and disposal of sewage sludge	900	50	air
Electroplating, Incineration of Plastics, and resmelting of scrap	540	30	air, water, solid waste

Source: SRI international, Cadmium Use and Substitutes for EPA, Menlo Park, California, 1980.

Although in 1979, more than one-half of the total cadmium consumption in the U.S. was in electroplating operations, cadmium use in this industry has decreased from 6 million pounds in 1974 to 5.2 million pounds in 1979 (Table 26).

Cadmium coatings protect other metals such as iron and steel in corrosive alkaline and saline environments. The cadmium products of corrosion are abraded or erode from the surface uniformly, with relatively little distortion of the original coated dimensions of the protected part and with no significant change in its appearance.

The ductility[1/] of cadmium coatings prevents cracking and separation of the coating from the part when loads are applied and/or the part is flexed. In addition, ductility allows the coating to expand and contract at the same rate as the part when temperature cycling occurs. Coating adherence is thereby maintained.

The lubricity of cadmium coatings reduces or eliminates seizure and galling under conditions of sliding friction between metal pieces. The lubricity is maintained throughout repeated cycles of sliding contact, as when threaded fasteners are removed and replaced.

Cadmium coatings adhere to most of the common solder alloys. This characteristic is used to advantage especially in hermetically sealing the long, crimped joints of thin gauge steel containers and in making electrical contact to cadmium-coated parts.

[1/] Capability to be applied on very thin parts.

TABLE 26

SHIFTS IN CADMIUM USE

Use Category	Percent of Total Use 1974	Percent of Total Use 1979	Millions in Pounds 1974	Millions in Pounds 1979
Electroplating	48%	51%	6.0	5.2
Pigments	18	13	2.2	1.3
Stabilizers	16	11	2.0	1.1
Batteries	10	22	1.2	2.3
Other	8	3	1.0	0.3
TOTAL	100%	100%	12.4	10.2

Sources: SRI International and U.S. Bureau of Mines, Mineral Commodity Summaries, on various commodities.

Because the electrical conductivity of cadmium coatings is good, cadmium-plated steel electrical hardware can often adequately substitute for copper, especially when the contact is maintained under mechanical load in a marine environment.

The silver-to-grey appearance of cadmium coatings is not only aesthetically acceptable, but it also provides a good optical background against which base metal rusting can be easily detected during inspections of parts that are in service.

Cadmium is considered easier to electroplate than most metals. It can produce acceptable coatings despite relatively wide variations in the following characteristics: surface preparation of parts to be plated; plating bath temperature, composition, and concentration; orientation of parts being plated to the electrode; and plating voltage and current density.

Cadmium is electroplated from cyanide solutions, containing cadmium as oxide or cyanide, sodium cyanide and sodium hydroxide or fluoroborate solutions which are purchased as liquid concentrates containing cadmium fluoroborate, fluoboric acid, boric acid and ammonium fluoroborate. Brighteners and grain refiners in the cyanide bath can be metallic, such as nickel, cobalt, molybdenum and selenium, or organic such as gelatin, coumarin, sugars, sulfonic acid derivatives, and aromatic aldehydes. Licorice is suggested for use in fluoroborate solutions. Most additives are proprietary. The cyanide bath has the lower cadmium concentration of 26 g/l (3.5 oz/gal) with a total cyanide concentration nearly four times as great as the cadmium concentration. The fluoroborate bath contains 95 g/l (12.6 oz/gal) cadmium and therefore contributes four times the amount of cadium to raw waste than does the cyanide bath. Water use may be further increased because of the greater viscosity of the fluoroborate baths and the resulting higher dragout.

The use of cadmium in electroplating has several substitutes, one of which is zinc. The principal use categories have varied over time and change is expected to continue. The current estimates of the relative importance of use categories are given in Table 27. Examination of the products in each of these categories has often shown that in many instances, not all of cadmium's properties are needed in the product for which it is used, and so substitution is possible. According to a recent study for EPA:

> In summary, zinc, zinc/tin, zinc/nickel, IVD aluminum and proprietary sacrificial coatings such as Dacromet 320 are the likely substitutes for most cadmium electroplated coatings. Copper, silver, chromium and lead will also be used to a lesser extent.

The characteristics of cadmium and these substitutes are in Table 28.[1]

Figure 2 presents a schematic flow chart for water flow in cadmium plating. As shown there, the waterborne wastes from electroplating operations containing cadmium are treated by an in-line treatment system shown in Figure 3. Unfortunately, these treatment operations, as well as the treatment by publicly-owned treatment works (POTWs) do not remove all cadmium wastes. As stated in a recent EPA study:[2]

> Data from 110 POTWs show that 75 percent of the primary plants, 57 percent of the trickling filter plants and 66

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[1] SRI International, Cadmium Use and Substitutes, Menlo Park, California, 1980.

[2] EPA, Electroplating Point Source Category, 440/1-79/003, Washington, D.C., 1979.

TABLE 27

ELECTROPLATE CADMIUM USE

Category	Percent of Use
Electrical goods, electronic gear, and consumer appliances	30
Industrial fasteners & hardware	30
Aircraft & aerospace fasteners	15
Automobiles	20
Ordnance & munitions	5
	100

Source: SRI International, op. cit.

TABLE 28

SELECTED CHARACTERISTCS OF CADMIUM ELECTROPLATE AND COMMERCIAL SUBSTITUTE COATINGS

	Corrosion Resistance	Ductility	Lubricity	Coverage Uniformity	Solderability	Electrical Conductivity	Appearance	Ease of Application	Relative Cost	Problems
Cadmium	Best in marine environment; good to excellent	Good	Excellent	Excellent	Good	High	Maintains silvery white luster	Electroplates easily	1	Toxic
Zinc	Lower than cadmium	Lower than cadmium	Poor	Good	Less than cadmium	Lower than cadmium	Forms bulky white rust	Electroplates easily	0.1	Forms bulky corrosion products
Zinc/tin	Lower than zinc	Good	Good	Fair	Good	High	Maintains luster	Electroplates with tight controls	2	Commercial, but not fully characterized
Zinc/nickel	Good to excellent	Good	Good	Fair	Good	High	Maintains luster	Electroplates with tight controls	2	Commercial, but not fully characterized
Zinc/chromium (Dacromet 320)	Good to excellent	Fair	Good	Poor	?	High	Maintains appearance	Not reproducible at all installations	1	Commercial, but coating conditions require careful controls
Aluminum (ion-vapor deposited)	Good to excellent	Good	Good	Fair	Poor	High	Maintains luster	Requires special equipment	1.5	Commercial, but requires special equipment and careful controls
Copper	Poor	Good	Good	Good	Good	High	Tarnishes	Electroplates with moderate controls	0.1	Corrodes easily
Silver	Fair	Good	Poor	Good	Good	Highest	Tarnishes	Electroplates with moderate controls	100	Expensive
Lead	Good in industrial environment	Good	Fair	Fair to poor	Good with tin added	Fair	Maintains dark luster	Dip coated easily	0.1	Toxic
Chromium	Good to excellent	Fair	Excellent	Good	Poor	High	Maintains shine	Electroplates with moderate controls	5	Expensive

SOURCE: SRI International, Cadmium Use and Substitutes, for EPA, Menlo Park, California, 1980.

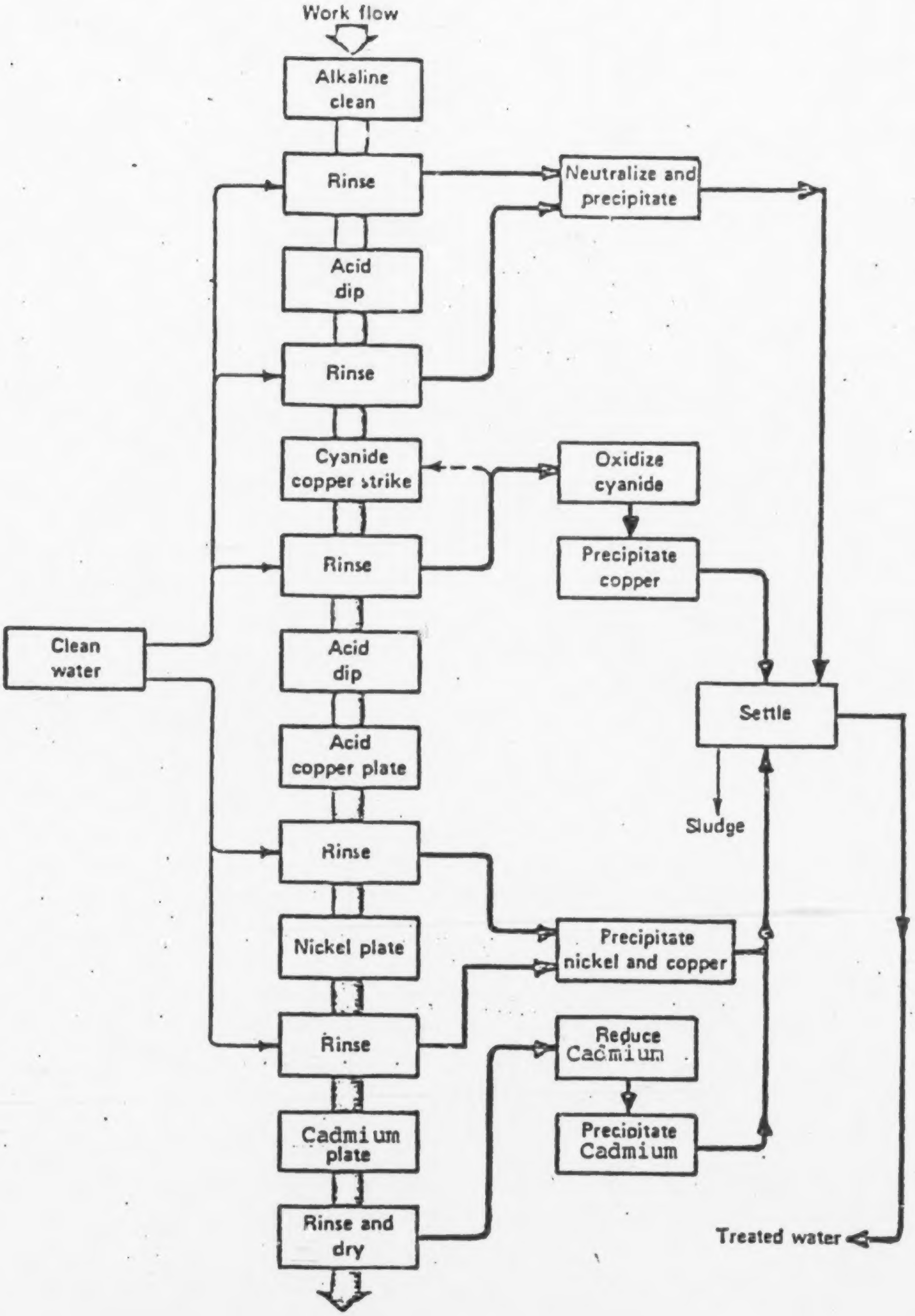
Work flow
Alkaline clean
Rinse
Acid dip
Rinse
Cyanide copper strike
Rinse
Acid dip
Acid copper plate
Rinse
Nickel plate
Rinse
Cadmium plate
Rinse and dry
Clean water
Neutralize and precipitate
Oxidize cyanide
Precipitate copper
Settle
Sludge
Precipitate nickel and copper
Reduce Cadmium
Precipitate Cadmium
Treated water

FIGURE 2 SCHEMATIC FLOW CHART FOR WATER FLOW IN CADMIUM PLATING

SOURCE: SRI International, Cadmium Use and Substitutes, for EPA, Menlo Park, California, 1980.

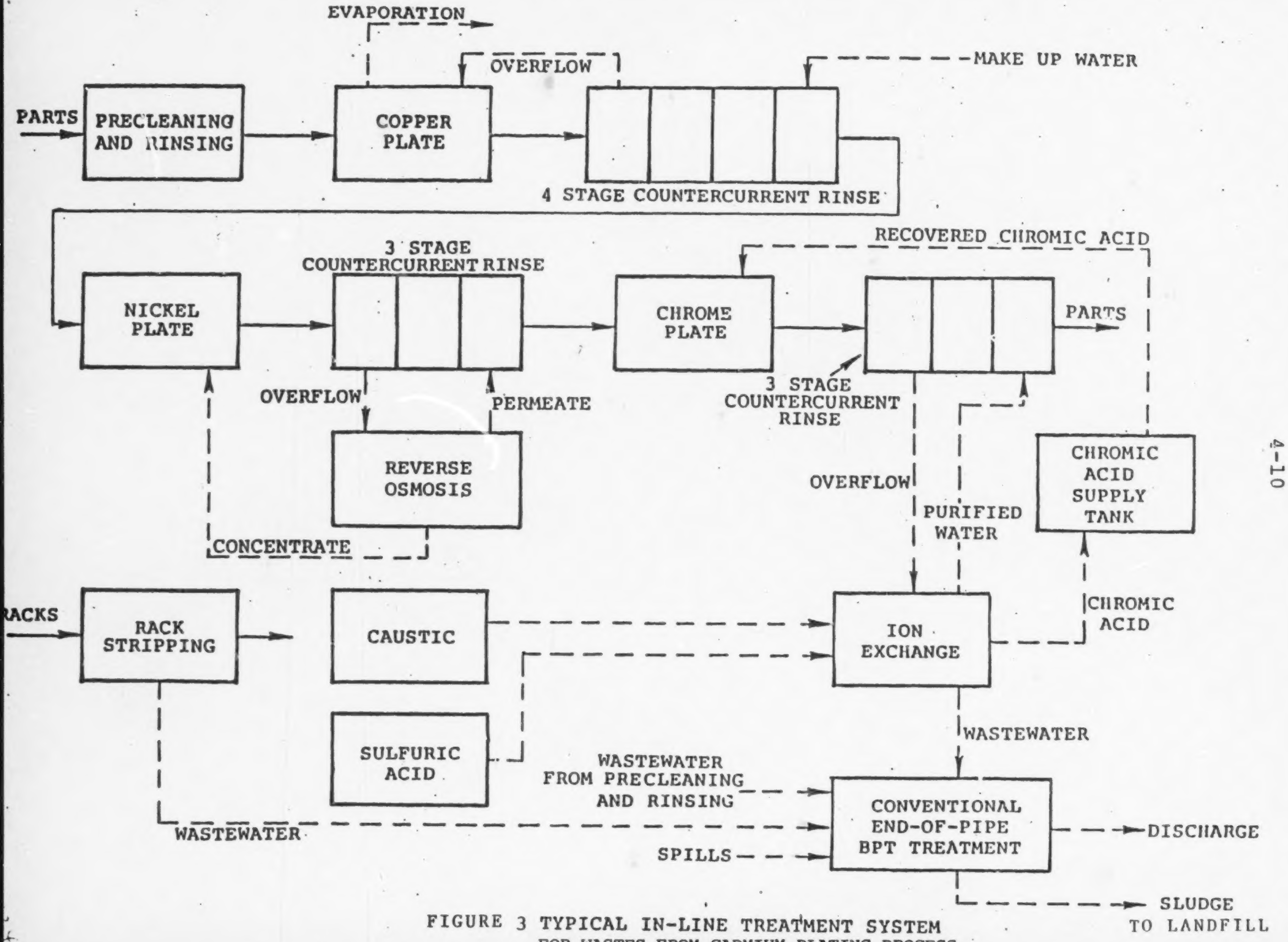
EVAPORATION
OVERFLOW
MAKE UP WATER
PARTS
PRECLEANING AND RINSING
COPPER PLATE
4 STAGE COUNTERCURRENT RINSE
RECOVERED CHROMIC ACID
3 STAGE COUNTERCURRENT RINSE
NICKEL PLATE
CHROME PLATE
PARTS
OVERFLOW
PERMEATE
3 STAGE COUNTERCURRENT RINSE
REVERSE OSMOSIS
OVERFLOW
PURIFIED WATER
CHROMIC ACID SUPPLY TANK
CONCENTRATE
ACKS
RACK STRIPPING
CAUSTIC
ION EXCHANGE
CHROMIC ACID
SULFURIC ACID
WASTEWATER
WASTEWATER FROM PRECLEANING AND RINSING
CONVENTIONAL END-OF-PIPE BPT TREATMENT
DISCHARGE
WASTEWATER
SPILLS
SLUDGE TO LANDFILL

FIGURE 3 TYPICAL IN-LINE TREATMENT SYSTEM
FOR WASTES FROM CADMIUM PLATING PROCESS

SOURCE: SRI International, Cadmium Use and Substitutes, for EPA, Menlo Park, California. 1980.

percent of the activated sludge plants allowed over 90 percent of the influent cadmium to pass through to the POTW effluent. Only 2 of the 110 POTWs allowed less than 20 percent pass through, and none allowed less than 10 percent pass through. Data from 145 POTWs show POTW effluent concentrations ranged from 0.001 to 1.97 mg/l (Mean 0.028 mg/l, standard deviation 0.167).

The cadmium which passes through the POTW to the effluent is discharged to ambient surface water. Cadmium is toxic to aquatic organisms at levels typically observed in POTW effluents. For example, the Cadmium Ambient Water Quality Criteria Document (PB-292-423) cites:

- 96 hr LV50 for chinook salmon is reported as 0.0018 mg/l,
- 96 hr LC50 for rainbow trout is reported as 0.0013 mg/l, and
- 48 hr LC50 for the invertebrate cladoceran is reported as 0.007 mg/l.

Cadmium has been selected as a pollutant parameter due to its extremely high toxicity to humans and aquatic organisms.

Substitution of cadmium in electroplating operations, while only a partial cure for cadmium releases, would result in substantial reductions (about 30% of all releases) in the environmental cadmium load.

Environmental Implications Resulting from Substitution

Cadmium enters our environment directly as a mineral resource used in industrial activities; indirectly as a by-product of agricultural, construction, energy production, and transportation activities; and naturally as an element in food, water, and the earth's crust. EPA traced many of its emissions into the atmosphere but they have been much less successful in finding sources of waste cadmium in surface waters. Likewise, data on the amount of cadmium discarded to landfill are nonexistent, although strong inferences can be made on the basis of known dispositions of most cadmium-containing products.

The extraction and refining of zinc, lead and copper ores is perhaps the single most important source of cadmium pollution.[1] It is found in flotation tailing, wastewater treatment tailing pond sediment, and other sources at mining and refining sites. Much of the cadmium in these ores is recoverable. Cadmium is purified as a by-product in the extraction of zinc, lead, and copper from their ores. Consequently, the amount of cadmium produced is dependent upon the production of these other metals. The Bureau of Mines[2] has developed regression equations which relate cadmium production to both cadmium prices and zinc production. High cadmium prices encourage the importation of zinc ores and flue dusts.

The scattered evidence available from EPA[3] and other sources on industrial flows to land and water are limited. The best data on air emissions are from W. E. Davis & Associates,[4] but are also limited and not precise.

1/ Kendall D. Mall, Hazardous Wastes: A Risk-Benefit Framework Applied to Cadmium and Asbestos, Stanford Research Institute, prepared for EPA, 1975.

2/ A. Petrick, et al., "The Economics of By-Product Metals","II. Lead, Zinc, Uranium, Rare Earth, Iron, Aluminum, Titanium and Lithium Systems", Bureau of Mines Information Circular 8570 (1978).

3/ R.S. Ottinger, et al., "Recommended Methods of Reduction, Neutralization, Recovery, or Disposal of Hazardous Wastes", 16 Volumes prepared for EPA by TRW Systems Group, PB224579, Set/As, Vol. XIV (February 1973).

4/ "National Inventory of Sources and Emissions: Cadmium, Nickel, and Asbestos -- 1968", (Cadmium, Section I), PB 192250, prepared by W.E. Davis & Associates, Leawood, Kansas, for Air Pollution Control Administration (February 1970).

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No cadmium air emissions are reported for the electroplating industry by Davis.[1/] Similarly, Fulkerson[2/] assigns no discharge to sewage from electroplating. However, these investigators appear to be in the minority since numerous other investigators have found large quantities of cadmium discharges from electroplating. TRW[3/] estimates that this industry is the largest cadmium polluter of our sewers, with an estimated loading of 514 metric tons per year.

The substitute for cadmium -- zinc -- also produces hazardous wastes. Since cadmium is a by-product of zinc refining, the substitution of zinc for cadmium in electroplating may not reduce the total amount of cadmium produced, nevertheless, substitution will reduce the amount of cadmium-bearing wastes discharged to the environment from the electroplating industry.

However, other hazardous wastes produced from zinc electroplating include cyanide and chromate. Oxidative treatment can be used to remove cyanide from the waste, and reductive treatment can remove hexavalent chromium. Lime can then be used to precipitate the zinc itself from waste plating solutions although the sludge produced is also a hazardous waste. These solutions typically contain 70-150 milligrams of zinc per liter of solution.[4/]

1/ "National Inventory of Sources and Emissions: Cadmium, Nickel, and Asbestos--1968", (Cadmium, Section IO, PB 192250, prepared by W. E. Davis & Associates, Leawood, Kansas, for Air Pollution Control Administration (February 1970).

2/ Fulkerson, W., et al., "Cadmium - The Dissipated Element", ORNL NSF-EP-21, supported by the National Science Foundation RANN Program, Oak Ridge National Laboratory, Oak Ridge, Tennessee (January 1973).

3/ R.S. Ottinger, et al., "Recommended Methods of Reduction, Neutralization, Recovery, or Disposal of Hazardous Wastes", 16 Volumes prepared for EPA by TRW Systems Group, PB224579, Set/As, Vol. XIV (February 1973).

4/ Watson, M.R., Pollution Control in Metal Finishing, Park Ridge, N.J.: Noyes Data Corp., 1973, p. 242.

The applicable waste treatment system elements are the same for treatment of zinc electroplating wastes as for cadmium electroplating wastes. Both need the cyanide oxidation element, chromuim reduction element, clarification element, and sludge drying element. This is because the most popular electroplating for both metals are cyanide based.

A key difference, however, is the fraction of metal in the raw waste load of total metals discharged. For plants using cadmium, the median fraction of the metal in the raw waste load is .05 while, for plants using zinc, the fraction is .21 of the raw waste load total metals discharged.[1] Thus there is a significant difference in the amount of plating metals entering the treatment system. Absent an economical recovery system, larger amounts of the plating metal will accordingly be disposed of in the total waste stream.

Parties Impacted by Cadmium Substitution in Electroplating

Analysis of the electroplating industry suggests that cadmium substitution in electroplating will impact on the following parties:

1) Producers of cadmium;

2) Electroplating industry;

3) Users of electroplated products; and

4) Producers of substitute metals.

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[1] EPA, Development Document for Existing Source Pretreatment Standards for the Electroplating Point Source Category, EPA -40/1-79/003, Aug. 1979, p. 371. Note that the units used by EPA are fractions of raw waste load total cadmium discharged, i.e., medium fraction of 0.05 equals 5%.

Impact on Cadmium Producers

Impacts of cadmium substitution in electroplating on cadmium producers will be significant, since the electroplating industry absorbs 51 percent of total cadmium demand. (Table 27.)

Impacts on Electroplating Industry

Impacts of cadmium substitution in electroplating on this industry are not fully clear. Interviews with some industry experts suggest no impact at all or even improved profit margins, while others anticipate certain difficulties. In both cases, the potential impacts would result primarily from the need to frequently change electroplating medium due to the use of different cadmium substitutes for different applications. Those who claim no impact from this substitution maintain that the electroplating industry has considerable experience in changes of electroplating medium and that use of several different substitutes for cadmium will allow the electroplaters to increase their prices and revenues.

Those in industry who anticipate difficulties resulting from cadmium substitution maintain that none of the substitute products are equal to cadmium in electroplating activities. They further maintain that use of different materials will require additional technical knowledge and experience. With regard to the latter factor, these industry experts suggest that unit costs in the elctroplating industry depend significantly on the firms' position on the "learning curve" and that use of new materials in place of cadmium will place these firms in a position on a learning curve where unit costs are high.

All industry experts agree that substitution of cadmium with other materials will not require additional capital investments.

Impacts on Users of Electroplated Products

Impacts of cadmium substitution on users of electroplated products depends, of course, on the characteristics of the substitute materials as compared with cadmium. The available information suggests that comparable materials can be readily found. For example, a recent report[1] indicates that IBM examined the uses of approximately 2,500 stock cadmium-plated parts and concluded that only 60 of these required cadmium for its metallurgical properties. The remainder was plated for corrosion protection only and IBM switched to zinc plating when possible. Composite coatings such as zinc plating followed by a water-emulsion wax were substituted in some instances where lubricity was needed. In a similar manner, adequate substitutions were found for all but a dozen of the remaining 2,440 parts that required corrosion protection. This experience could be reasonably extrapolated to the whole category of electrical goods, electronic gears, and consumer applicances, which includes IBM's products.

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[1] E. Dage, et al., Proceedings of the Workshop on Alternatives for Cadmium Electroplating in Metal Fasteners, prepared for Office of Toxic Substances, Washington, D.C. (March 1979).

The Department of Defense[1] has also attempted to reduce cadmium use. During the first phase of this effort, the process specifications for cadmium electroplating were identified and studied to determine how effluents might be better controlled or reduced. The second phase of the reduction plan involved indentification of all military hardware specifications that require, allow, or advise the use of cadmium electroplating. During the third phase, those parts or equipment specifications that mandate cadmium use are to be reviewed. Departure from cadmium use is to be recommended wherever possible. When the specifications allow or advise the use of cadmium, such options are to be deleted. This work is expected to be completed in approximately one year; it should significantly reduce the use of cadmium in military hardware to perhaps one-tenth of its present use.

Cadmium's corrosion protection is particularly useful in the marine environment, but investigations by the Tin Research Institute have shown that tin/zinc alloy platings offer corrosion protection superior to cadmium in the industrial environment and offer better solderability as well. In general, zinc, zinc/tin, and zinc/nickel alloys are potential substitutes when corrosion protection is needed for those items included as cadmium-plated industrial fasteners and hardware. Diamond Shamrock has developed Dacromet 320, a proprietary mixture of zinc flake, chromium, and an organic binder that is heat-treated after application to remove the organic binder. Because the coating offers good corrosion protection and adequate lubricity, its use as a cadmium substitute for industrial fasteners and hardware is increasing.

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[1] See, for example: Director Environmental Policy OASD (EEES), Memorandum Cadmium Use in Electronic Systems Procurement, April 13, 1979, and Defense Industrial Resources Support Office, Memorandum Emissions from Electroplating Operations, June 3, 1979.

A commercially available general substitute for cadmium-plated aircraft and aerospace fasteners is ion-vapor-deposited (IVD) aluminum. This practically pure aluminum is more compatible with the aluminum alloys it protects than is cadmium.

Impacts on Cadmium Imports

Since more than one-half of cadmium used in domestic consumption is imported (Table 29), elimination or reduction of cadmium used in electroplating, which represents about half of domestic consumption, will severely impact on cadmium importers. The value of cadmium imports is approximately $15.6 million, and the margin to importers about $1.8 million, which would be lost if the cadmium imports would be eliminated because of reduced demand. Much of this can be expected to be made up by increased imports of substitutes, especially if zinc is the substitute, since the U.S. is dependent on imports for much of its zinc supply.1/

1/ L.L. Fischman, World Mineral Trends and U.S. Supply Problems, Washington, D.C., Resources for the Future, 1980, p. 120 (interestingly, substitution of zinc for cadmium would result in a shifting of the pollutant load from the U.S. to other countries since most of the zinc imported into the U.S. is refined, with the cadmium waste remaining in the country of export).

TABLE 29

SALIENT CADMIUM STATISTICS, 1975-1979

	1975	1979
Production[1] .... metric tons	1,990	1,715
Exports .... metric tons	180	211
Imports for consumption, metric tons	2,375	2,572
Apparent consumption ... metric tons	3,055	4,817

[1] Primary and secondary cadmium metal. Includes metal content of cadmium sponge used directly in production of compounds.

SOURCE: SRI International, Cadmium Use and Substitutes, for EPA, Menlo Park, California, 1980.

Conclusion

The electroplating industry is the most important user of cadmium. Significant reductions in cadmium use can be achieved, therefore, if substitutes are developed for use in electroplating. Zinc is one promising substitute, and while there are other substitute materials, these are too costly (i.e., silver and chromium), or toxic (i.e., lead), or require much more extensive and expensive machinery in application (i.e., aluminum).

Thus, for practical purposes cadmium coated end-products have only one principal substitute -- zinc coated end-products.

Substitution of cadmium with zinc in electroplating would eliminate annual cadmium emissions from these operations estimated at 540 metric tons per annum.

This, of course, would result in additional demand for zinc and in emissions of small amounts of cadmium in the refining process. The issue before us is whether the reduction of cadmium emissions from electroplating operations by substituting zinc for cadmium is significantly larger than additional emissions of cadmium resulting from additional zinc refining, required by additional demand for zinc as a substitute for cadmium in electroplating.

In the course of refining the zinc, about .36 ton of cadmium is released for each 1,000 tons of zinc (Table 25). Assuming a one-for-one substitution of zinc for cadmium, 6,300 additional tons of zinc would be needed annually. This would result in an increase in cadmium releases of 2.27 metric tons per year for zinc refining, an increase of less than one percent over existing release levels. This is insignificant in comparison to the 540 metric tons of cadmium released in the course of electroplating and other industrial uses (Table 25).

Accordingly, the substitution of zinc for cadmium appears to be quite sound from the standpoint of reducing cadmium releases. Similarly, economics and technology are not bars to cadmium substitution.

The principal reason why the cadmium substitution with zinc in electroplating operations has not taken place has been Department of Defense procurement regulations which favor cadmium use because of its marginally superior characteristics over zinc, especially in military hardware which must stand up to much more rigorous use.

As noted in the above discussion, the Department of Defense has begun to modify its procurement regulations with respect to cadmium and cadmium substitution with zinc. However, it is useful to elaborate on the past impact of the Department of Defense regulations because, while requiring the use of cadmium in electroplating of military hardware, these have only effectively encouraged the use of cadmium in electroplating of non-military goods. This results from the fact that switching from one metal (i.e., cadmium) to another (zinc) in electroplating operations is time-consuming and costly. Note that while zinc is considerably less costly as compared to cadmium, the increased cadmium costs are passed on to the purchasers of electroplated products.

Since cadmium in all respects, except for hazardous waste generation, is equal or even better than zinc in electroplating operations, there is no inducement for the electroplating industry to substitute zinc for cadmium in non-defense electroplating applications. Thus, these Department of Defense regulations have impact beyond defense-related procurement on this specific end-product substitution. Whether other similar government regulations impact on other end-product substitution is not clear, although such a possibility exists. To generalize further, it is quite possible that at any time there exist specifications, standards, requirements and regulations in general which impact on the properties, characteristics or composition of a certain proportion of products. The producers of these products will attempt to manufacture the entire output of these products according to these specifications for reasons of production cost reduction.

To put it simply, there is evidence that changes in end-products during a production run are avoided by manufacturers whenever and wherever possible.[1/]

[1/] Excellent proof of this can be seen in the difficulty experienced by the Department of Defense in obtaining certain supplies, according to Department of Defense specifications, from firms which manufacture such supplies for the private sector. See: Jacques Gansler, The Defense Industry, New York, 1980.

CHAPTER V

SUBSTITUTES FOR CREOSOTE TREATED WOOD PILING

Wood piling used in marine and other applications must be treated with creosote and related chemicals to preserve it. The treatment process (described below) generates creosote and other hazardous chemical discharges which are very difficult to control.

The wood preserving industry is composed of a large number of small, privately owned plants and a few larger establishments. Larger establishments are generally either:

- Owned by companies whose major source of income is not wood preserving: e.g., Koppers, Kerr-McGee Chemical Corp., Southern Wood Piedmont Col., and International Paper Company; or,
- Owned by companies which are primarily wood preservers; e.g., J. H. Baxter & Co., Wyckoff Co.

Each of these firms operates at numerous locations. There were approximately 302 companies and 415 wood preserving plants in the country in 1976.

The wood preserving companies vary considerably in both sales and number of wood preserving operations. Of 302 wood preserving companies, 263 (87%) are single-plant firms, 39 (13%) are multi-plant firms. Koppers Company operates 25 plants; the other multi-plant firms operate 10 or fewer plants.

Available information shows that total annual sales of these companies, including sales from other operations, range from less than $200,000 to over $1 billion.

The wood preserving industry has a large number of small firms. However, on the basis of pressure tank capacity, the 10 largest firms represent approximately 51 percent of the total industry. While actual production may not be directly correlated with pressure tank capacity because capacity utilization may vary and different products and different species of wood require varying treatment times, pressure tank capacity is an indicator of production capacity. In 1976, Koppers Co., Inc., represented 20 percent of total industry capacity, while the four largest firms represented 37 percent of total capacity.

From 1955 to 1979, the volume of wood treated with preservatives fluctuated from a low of 213.9 million cubic feet in 1962 to a peak production of 310.4 million cubic feet in 1979 (Table 31). Production was 257.2 million cubic feet in 1976, the most recent year for which data are available. The industry's historical peak production level, 356.6 million cubic feet, was in 1947, indicating that the long-term trend is down.

In the case of piling, the output has declined from a historical high of 21.1 million cubic feet in 1966 to 6.1 million cubic feet in 1979 because wood-treated piling has been substituted by other materials described below.

There have been significant decreases of wood piling output from the wood preserving industry because wood piling, especially that used for marine applications, has been substituted by:

- in-place concrete,
- driving concrete, and
- steel piling.

There are several reasons for this substitution. First, the large physical size of piling as compared to say railroad ties, plywood, etc., requires wood preserving equipment from which pollution emissions are very difficult to control. Thus a number of wood preserving firms have shut down this segment of business. Second, the useful life of treated wood piling, especially in marine use, is relatively short. Finally, there have been a number of technological developments related to the application of in-place concrete which have made this substitute for wood piling very attractive in terms of a much larger useful life as well as cost. The net result has been increasing substitution of wood piling with other materials.

Process Description

The wood preserving process consists of two basic steps: (1) conditioning the wood to reduce its natural moisture content and increase the permeability, and (2) impregnating the wood with the preservative. (See Table 30).

The conditioning step may be performed by one of several methods including (1) seasoning or drying wood in large, open yards; (2) kiln drying; (3) steaming the wood at elevated pressure in a retort followed by application of a vacuum; (4) heating the stock

TABLE 30

WOOD TREATED WITH PRESERVATIVES, 1955-1979
(millions of cubic feet)

Year	Piling	Total
1955	13.9	248.4
1960	16.1	216.1
1965	17.8	255.7
1970	15.1	260.3
1971	13.7	268.6
1972	14.3	272.6
1973	13.0	254.4
1974	13.3	274.7
1975	9.4	244.1
1976	8.5	257.2
1977	7.1	261.0
1978	6.3	281.2
1979	6.1	310.4

Source: Ernst and Ernst, Wood Preservation Statistics - 1979.

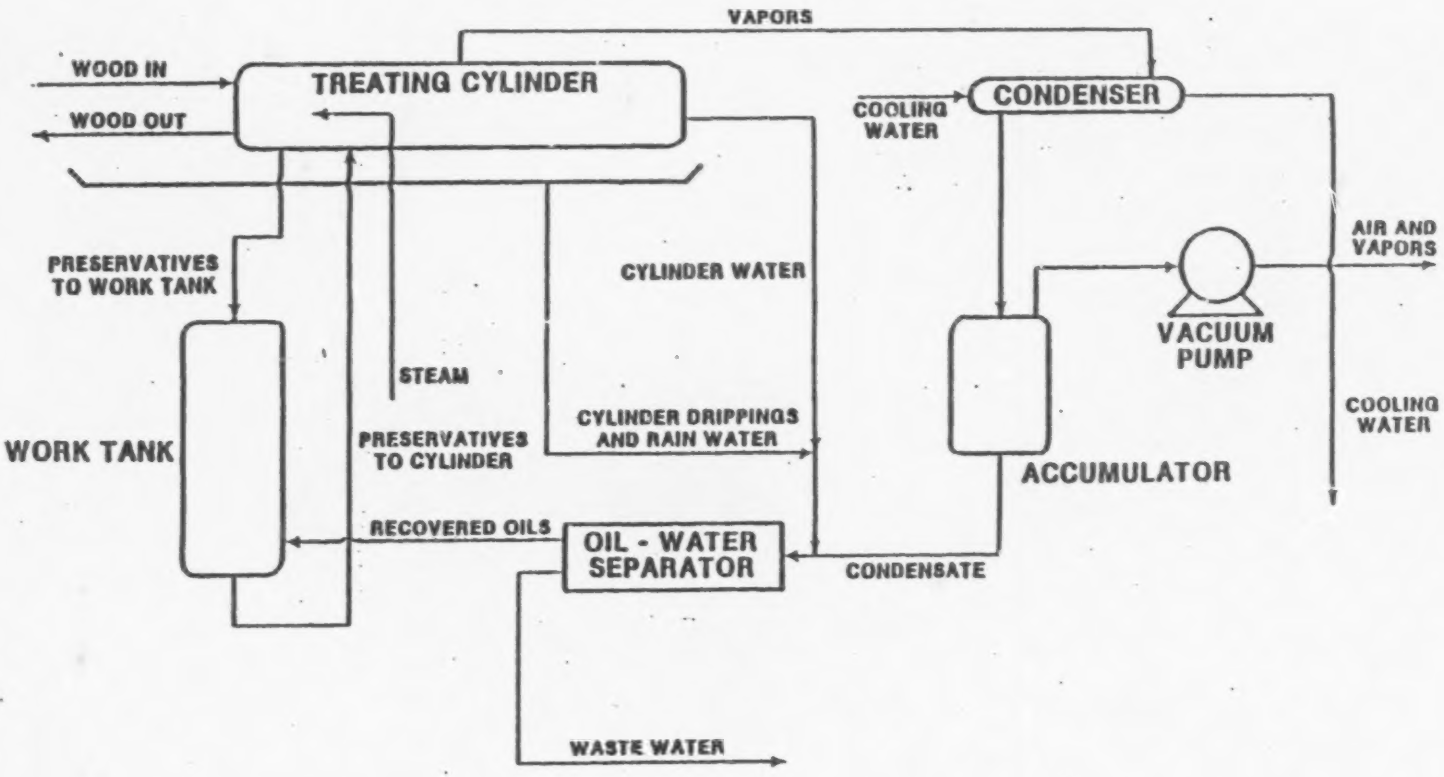
in a preservative bath under reduced pressure in a retort (Boulton process); or (5) vapor drying, heating of the unseasoned wood in a solvent to prepare it for preservative treatment. All of these conditioning methods have as their objective the reduction of moisture content of the unseasoned stock to a point where the required amount of preservative can be retained in the wood.

Conventional steam conditioning (open steaming) is a process in which unseasoned or partially seasoned stock is subjected to direct steam impingement at an elevated pressure in a retort. Steam condensate that forms in the retort exits through traps and is conducted to oil-water separators for removal of free oils. Removal of emulsified oils requires further treatment. Figure 4 shows a diagram of a typical open steaming wood preserving plant.

In closed steaming, a widely used variation of conventional steam conditioning, the steam needed for conditioning is generated *in situ* by covering the coils in the retort with water from a reservoir and heating the water by passing process steam through the coils. The water is returned to the reservoir after oil separation and reused during the next steaming cycle. Figure 5 shows a diagram of a typical closed steaming wood preserving plant.

FIGURE 4

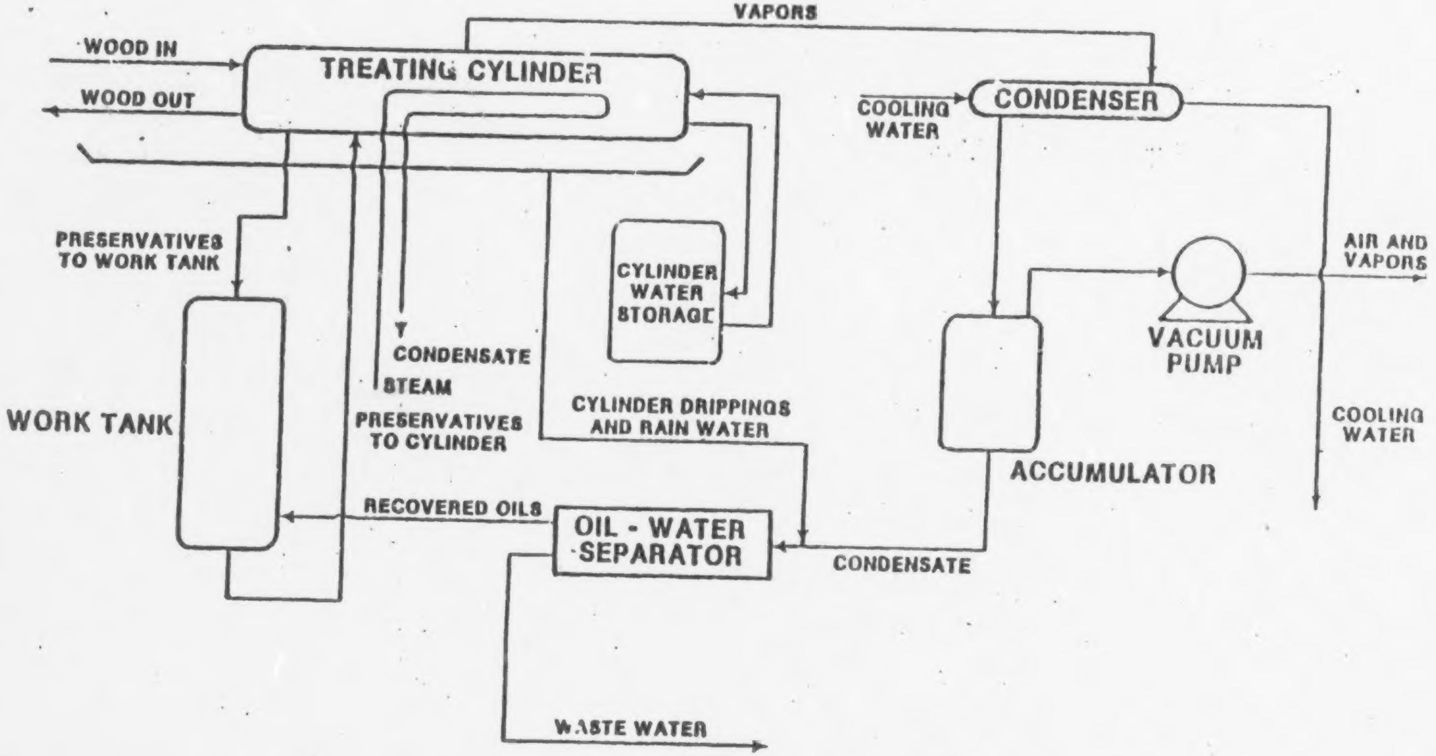
OPEN STEAMING PROCESS WOOD TREATING PLANT


VAPORS
WOOD IN
TREATING CYLINDER
WOOD OUT
COOLING WATER
CONDENSER
AIR AND VAPORS
PRESERVATIVES TO WORK TANK
CYLINDER WATER
VACUUM PUMP
STEAM
WORK TANK
PRESERVATIVES TO CYLINDER
CYLINDER DRIPPINGS AND RAIN WATER
COOLING WATER
ACCUMULATOR
RECOVERED OILS
OIL - WATER SEPARATOR
CONDENSATE
WASTE WATER

SOURCE: EPA, Guidance Development Document Effluent Limitations Guidelines and New Source Performance Standards for Wood Products Point Source Category, EPA 440/1-78/090.

FIGURE 5

CLOSED STEAMING PROCESS WOOD TREATING PLANT


VAPORS
WOOD IN
WOOD OUT
TREATING CYLINDER
COOLING WATER
CONDENSER
PRESERVATIVES TO WORK TANK
CYLINDER WATER STORAGE
AIR AND VAPORS
VACUUM PUMP
CONDENSATE
STEAM
WORK TANK
PRESERVATIVES TO CYLINDER
CYLINDER DRIPPINGS AND RAIN WATER
COOLING WATER
ACCUMULATOR
RECOVERED OILS
OIL - WATER SEPARATOR
CONDENSATE
WASTE WATER

SOURCE: EPA, Guidance Development Document Effluent Limitations Guidelines and New Source Performance Standards for Wood Products Point Source Category, EPA 440/1-78/090.

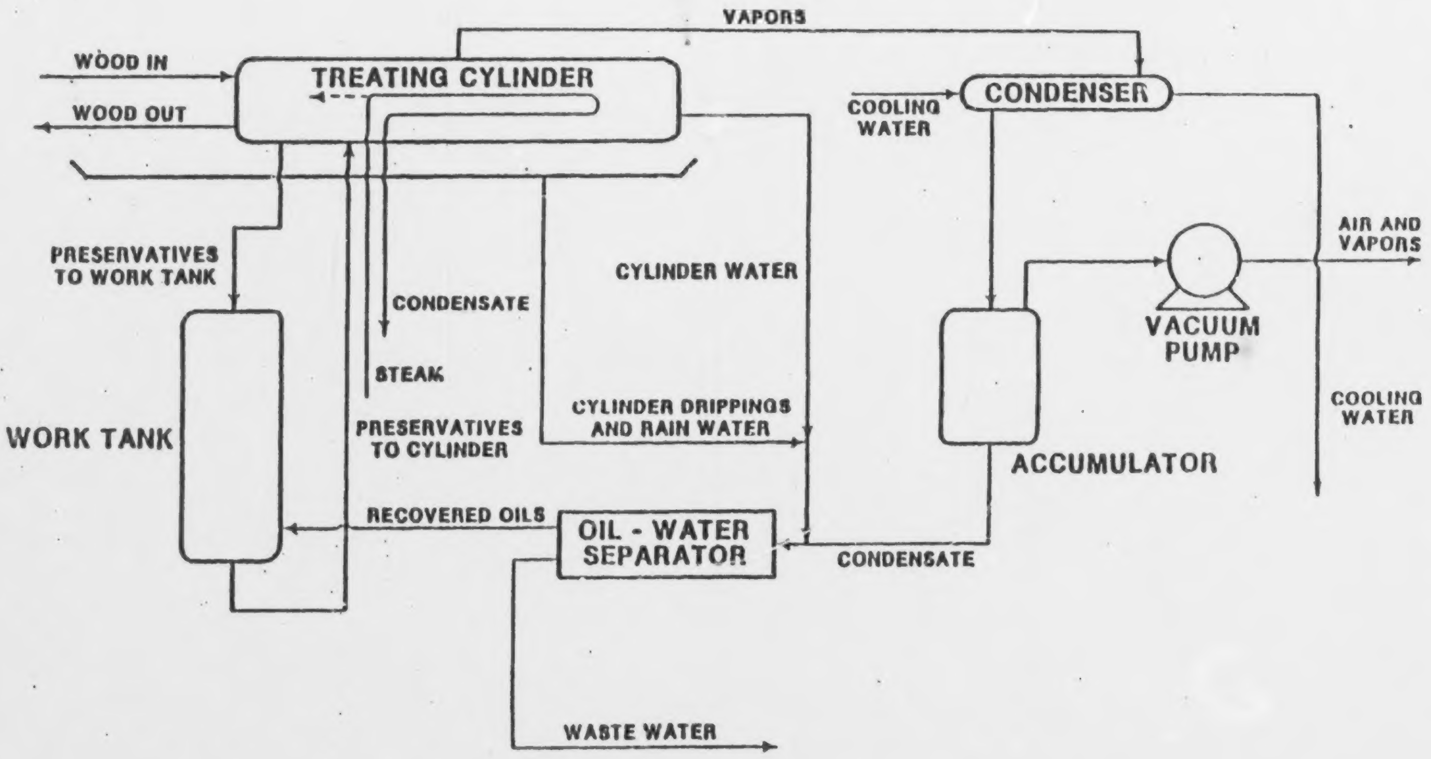
Modified closed steaming is a variation of the steam conditioning process in which steam condensate is allowed to accumulate in the retort during the steaming operation until it covers the heating coils.. At that point, direct steaming is discontinued and the remaining steam required for the cycle is generated within t retort by utilizing the heating coils. Upon completing the steaming cycle, the water in the cylinder is discarded after recovery of oils. Figure 6 shows a diagram of a typical modified steaming wood preserving plant.

Preconditioning is accomplished in the Boulton process by heating the stock in a preservative bath under reduced pressure in the retort. The preservative serves as a heat transfer medium. After the cylinder temperature has been raised to operating temperature, a vacuum is drawn and water removed in vapor form from the wood passes through a condenser to an oil-water separator where low-boiling fractions of the preservative are removed. The Boulton cycle may have a duration of 48 hours or longer for large poles and piling, a fact that accounts for the lower production per retort day as compared to plants that steam condition. Figure 7 illustrates the Boulton process.

The vapor-drying process, illustrated in Figure 8, consists essentially of exposing wood in a closed vessel to vapors from any one of many organic chemicals that are immiscible with water and have a narrow boiling range. Selected derivatives of petroleum and coal tar, such as xylol, high-flash naphtha, and Stoddard solvent,

FIGURE 6

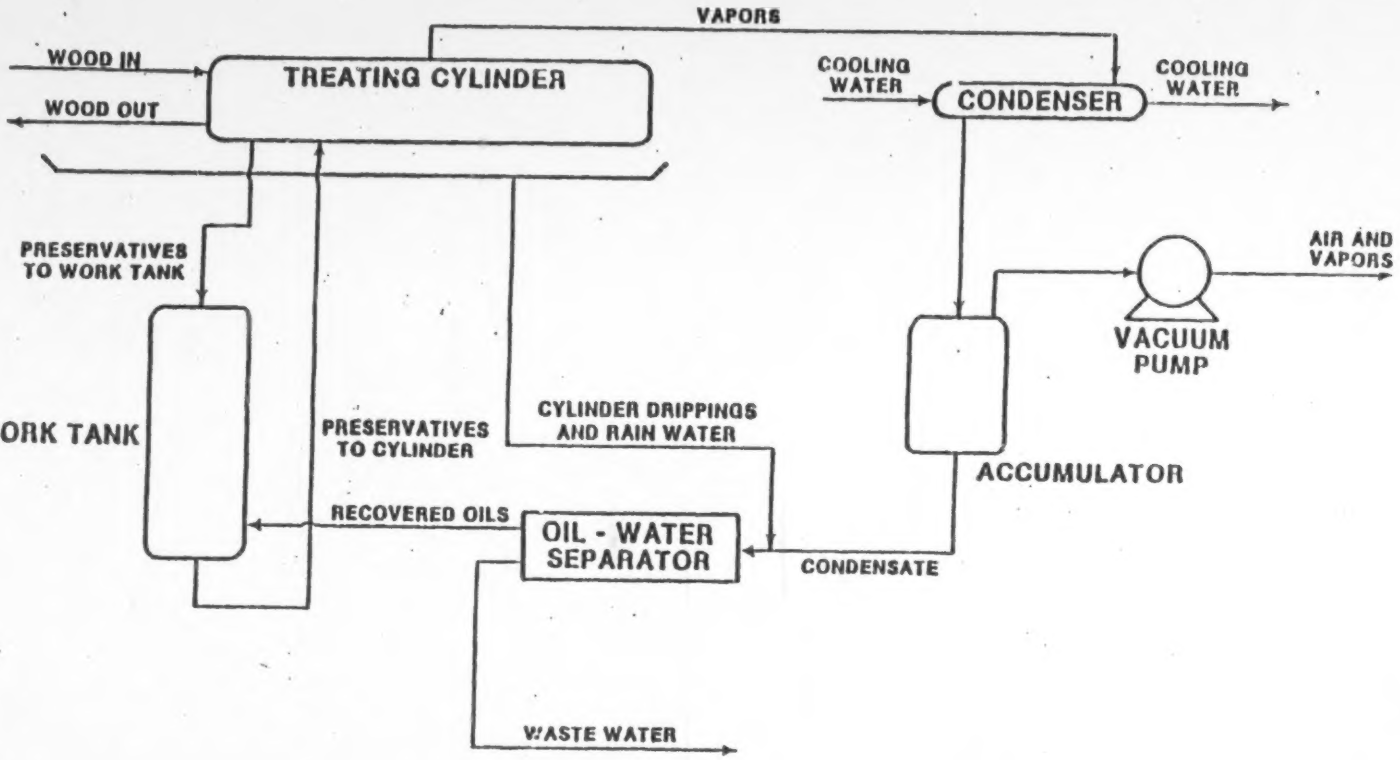
MODIFIED STEAMING PROCESS WOOD TREATING PLANT


VAPORS
WOOD IN
TREATING CYLINDER
WOOD OUT
COOLING WATER
CONDENSER
PRESERVATIVES TO WORK TANK
CYLINDER WATER
AIR AND VAPORS
CONDENSATE
VACUUM PUMP
STEAK
WORK TANK
CYLINDER DRIPPINGS AND RAIN WATER
PRESERVATIVES TO CYLINDER
COOLING WATER
ACCUMULATOR
RECOVERED OILS
OIL - WATER SEPARATOR
CONDENSATE
WASTE WATER

SOURCE: EPA, Guidance Development Document Effluent Limitation Guidelines and New Source Performance Standards for Wood Products Point Source Category, EPA 440/1-78/090.

FIGURE 7

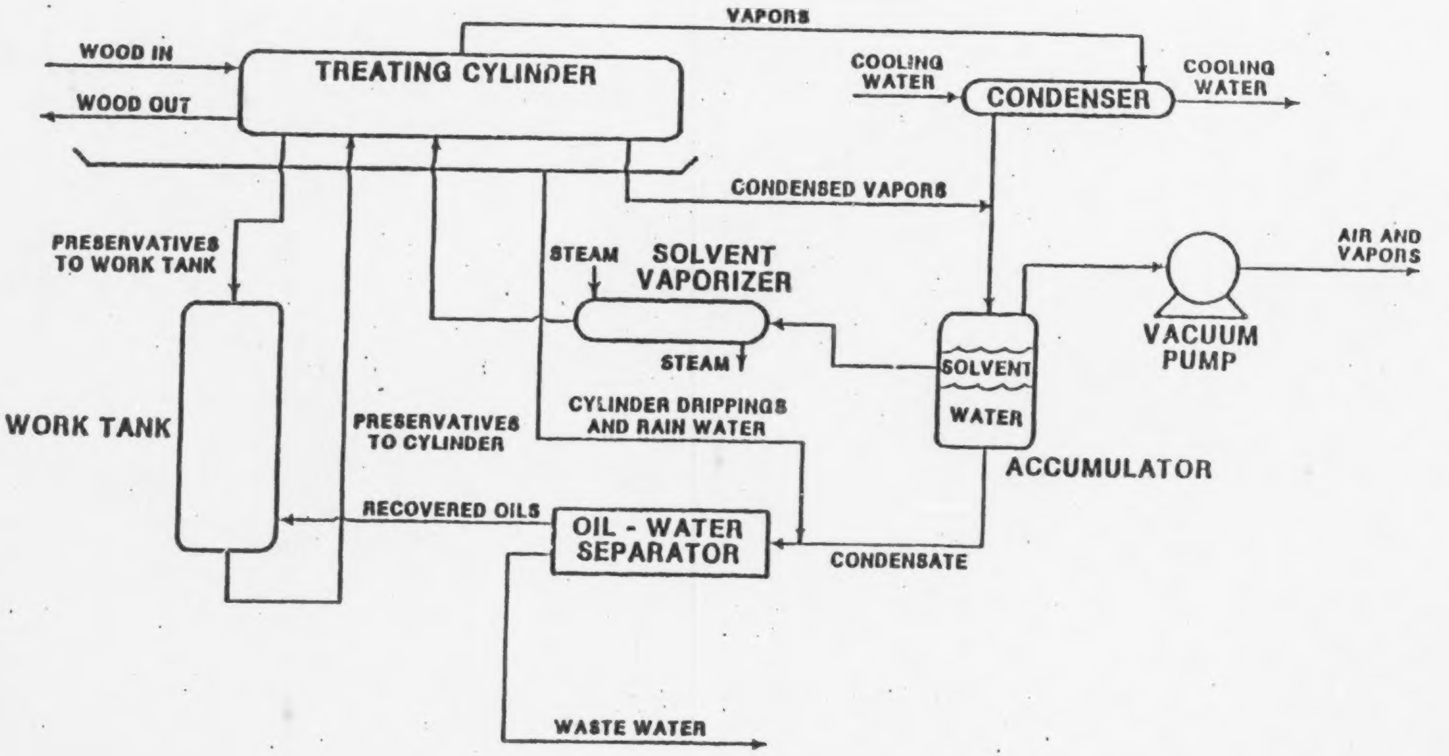
BOULTON WOOD TREATING PLANT


VAPORS
WOOD IN
WOOD OUT
TREATING CYLINDER
COOLING WATER
CONDENSER
COOLING WATER
PRESERVATIVES TO WORK TANK
AIR AND VAPORS
VACUUM PUMP
WORK TANK
PRESERVATIVES TO CYLINDER
CYLINDER DRIPPINGS AND RAIN WATER
ACCUMULATOR
RECOVERED OILS
OIL - WATER SEPARATOR
CONDENSATE
WASTE WATER

SOURCE: EPA, Guidance Development Document Effluent Limitations Guidelines and New Source Performance Standards for Wood Products Point Source Category, EPA 440/1-78/090.

FIGURE 8

VAPOR CONDITIONING PROCESS WOOD TREATING PLANT


VAPORS
WOOD IN
WOOD OUT
TREATING CYLINDER
COOLING WATER
CONDENSER
COOLING WATER
CONDENSED VAPORS
PRESERVATIVES TO WORK TANK
STEAM
SOLVENT VAPORIZER
AIR AND VAPORS
STEAM
SOLVENT
WATER
VACUUM PUMP
WORK TANK
PRESERVATIVES TO CYLINDER
CYLINDER DRIPPINGS AND RAIN WATER
ACCUMULATOR
RECOVERED OILS
OIL - WATER SEPARATOR
CONDENSATE
WASTE WATER

SOURCE: EPA, Guidance Development Document Effluent Limitations Guidelines and New Source Performance Standards for Wood Products Point Source Category, EPA 440/1-78/090.

are preferred; but numerous chemicals, including blends, can be and have been employed as drying agents in the process. Chemicals with initial boiling points of from 212°F to 400°F (100°C to 204°C) may be used.

Vapors for drying are generated by boiling the chemical in an evaporator. The vapors are conducted to the retort containing the wood, where they condense on the wood, give up their latent heat of vaporization, and cause the water in the wood to vaporize. The water vapor thus produced, along with excess organic vapor, is conducted from the vessel to a condenser and then to a gravity-type separator. The water layer is discharged from the separator and the organic chemical is returned to the evaporator for reuse.

At the termination of the heating period, the flow out of organic vapors to the vessel is stopped and a 30-minute to 2-hour vacuum is imposed to remove the condensed chemical absorbed by the wood, along with the additional water that is removed from the wood during the vacuum cycle. Since the drying vessel is usually also the retort used for preservative treatment, the wood can be treated immediately using any one of the standard preservative processes.

Following any of the above conditioning steps, the treatment step may be accomplished by either pressure or non-pressure processes.

Non-pressure (thermal) processes utilize open tanks which contain the preservative chemicals. Stock to be treated is immersed in the treating chemicals, which may be at ambient temperature, heated, or a combination thereof. Stock treated in nonpressure processes is normally conditioned by air seasoning or kiln drying.

Treatment methods employing pressure processes consist of three basic types, independent of the preconditioning method. Two of the pressure methods, referred to in the industry as "empty-cell" processes, are based on the principle that part of the preservative forced into the wood is expelled by entrapped air upon the release of pressure at the conclusion of the treating cycle, thus leaving the cell walls coated with preservative. The pressure cycle is followed by a vacuum to remove additional preservative. The retention of preservatives attained is controlled in part by the initial air pressure employed at the beginning of the cycle.

The third method, which is known as the "full-cell" process, differs from the other two in that the treating cycle is begun by evacuating the retort and breaking the vacuum with the preservative. The preservative is then forced into the wood under pressure, as in the other processes. Most of the preservative remains in the wood when the pressure is released. Retentions of preservatives achieved in this process are substantially higher than those achieved in the empty cell processes.

Stock treated by any of the three methods may be given a short steam treatment to "clean" the surface of poles and pilings and to reduce exudation of oil after the products are placed in service.

As clearly indicated in this description of processes used for wood preserving, the hazardous waste emissions occur from release of waste water into the environment, as described in more detail in the following section.

Hazardous Waste Generation

The most common preservatives used in wood preserving are creosote, pentachlorophenol, and various formulations of water-soluble, inorganic chemicals, the most common of which are salts of copper, chromium, and arsenic.

Consumption data for the principal preservatives for the period between 1971 and 1978 are given in Table 31. In terms of amount used, creosote in its various forms is the most important, followed by pentachlorophenol. Creosote and pentachlorophenol both produce phenol wastes.

The range of phenol and COD values for effluents from some representative preserving plants is presented in Table 32. The range of concentration is relatively large and is represented by factor of ten or more. In the case of phenol effluents from thirteen wood preserving plants, when phenol emissions expressed as mg/liter, these values range from 50 to 953, and represent the highest phenol emissions from industrial sources. The best average estimate of raw waste loadings for this industry, according to the EPA,[1/] is presented in Table 33.

On the basis of data presented in Table 33, the annual generation of phenol wastes by all 415 wood treatment plants is about 2.5 million pounds. Treatment of wood piling generates about 50 thousand pounds of phenol wastes.

[1/] EPA, Guidance Development Document Effluent Limitations Guidelines and New Source Performance Standards for Wood Products Point Source Category, EPA 440/1-78-090.

TABLE 31

CONSUMPTION OF PRINCIPAL PRESERVATIVES OF REPORTING PLANTS IN THE UNITED STATES, 1971-1978

Material	(Units)	Year 1971	1974	1978
Total Creosote	Million Kilograms	337	321	382
Total Petroleum	Million Kilograms	234	223	222
Pentachlorophenol [1]	Million Kilograms	14.5	19.7	11.3
Chromated Zinc Chloride [1]	Million Kilograms	0.6	0.2	0.4
CCA [1]	Million Kilograms	3.9	6.9	2.1

SOURCE: EPA, Guidance Development Document Effluent Limitations Guidelines and New Source Performance Standards for Wood Products Point Source Category, EPA 440/1-78/090.

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[1] In the EPA document these figures are given in terms of liters, Conversion from liters to kilograms have been accomplished assuming weight of these substances at 1.308 kilograms per liter.

TABLE 32

PHENOL AND COD VALUES FOR EFFLUENTS FROM THIRTEEN WOOD PRESERVING PLANTS

Plant Location	Phenol (mg/1)	COD (mg/1) Raw	COD (mg/1) After Flocculation	COD (mg/1) Percent Reduction
Mississippi	162	6,290	3,700	41
Mississippi	109	11,490	5,025	56
Mississippi	-	48,000	2,040	96
Mississippi	168	42,000	31,500	25
Mississippi	83	12,300	4,500	63
Mississippi	50	1,000	-	-
Virginia	192	9,330	3,180	66
Virginia	508	32,300	8,575	73
Georgia	119	7,440	2,360	68
Georgia	331	3,370	1,880	44
Georgia	123	17,100	3,830	78
Tennessee	953	1,990	1,990	0
Louisiana	104	10,500	6,070	42

SOURCE: EPA, Guidance Development Effluent Limitations Guidelines and New Source Performance Standards for Wood Products Point Source Category, EPA 440/1-78/090.

TABLE 33

AVERAGE RAW WASTE LOADINGS FOR TYPICAL WOOD-PRESERVING PLANT

Parameter	Raw Waste Loadings Parenthetical values = Pounds/1000 Cubic Feet (mg/l)	Raw Waste Loadings Parenthetical values = Pounds/1000 Cubic Feet Kg/1000 Cubic Meters Prod.	Raw Waste Loadings/Day(kg) Parenthetical values are in pounds Max.	Raw Waste Loadings/Day(kg) Parenthetical values are in pounds Min.	Raw Waste Loadings/Day(kg) Parenthetical values are in pounds Avg.
COD	19,269	5,378.4 (335.1)	1,651.9 (3,634.2)	502.9 (1,106.3)	1,016.0 (2,235.2)
Phenols	182	51.4 (3.2)	12.8 (28.2)	6.3 (13.8)	9.6 (21.1)
Oils and Grease	297	83.5 (5.2)	37.5 (82.5)	7.5 (16.4)	15.6 (34.4)
Total Solids	5,280	1,463.8 (91.2)	470.7 (1,035.5)	109.5 (240.9)	278.4 (612.5)
Dissolved Solids	4,571	1,276.0 (79.5)	387.4 (852.2)	93.5 (205.8)	241.0 (530.2)
Suspended Solids	710	199.0 (12.4)	87.2 (191.9)	12.2 (26.8)	37.5 (82.4)
pH		4.9			

Avg. flow = 52,990 lpd (14,000 gpd)
Void vol. of cylinders = ~~411 cubic~~ meters (14,517 cubic feet)
Est. 1971 Production = 53,867 cubic meters (1,902,258 cubic feet)
Avg. work days/yr. = 285
Avg. daily production = 189 cubic meters (6,674 cubic feet)
Preservatives - Creosote, Pentachlorophenol

SOURCE: EPA, *Guidance Development Document Effluent Limitations Guidelines and New Source Performance Standards for Wood Products Point Source Category*, EPA 440/1-78/090.

On the basis of data presented in Table 33, about 50 percent of all wastes generated is removed by conventional water pollution treatment plants, which leaves about 25 thousand pounds of phenol wastes discharged annually into the environment. Substitution of creosote treated wood piling by concrete and steel piling would eliminate discharge of these phenol wastes. In summary:

Total Annual Generation of Phenol Wastes by Wood Piling Treatment.	50 thousand lbs.
Phenol Wastes Treated and Destroyed by Treatment Plants.	50% or 25 thousand pounds
Phenol Wastes Discharged into Environment Through Water Discharge.	25 thousand lbs.

Hazardous Waste Generated by Substitutes

As stated above, the relative importance of treated wood piling has been steadily declining as to both the consumers of piling and the wood treatment industry. This is because of the increased use of substitutes, specifically steel piling and concrete piling.

Steel production results in a variety of hazardous wastes. Among these are phenols, cyanides, chlorides, chromium, and cadmium. Also produced are waste treatment products which are themselves hazardous wastes, including emission control dust and sludge, sludge from treatment of spent pickle liquor, and waste from treatment of quenching wastewaters.

Concrete, on the other hand, produces much less in the way of hazardous wastes. Indeed the major pollutant of any kind from concrete is dust. This dust is of two kinds -- cement dust and sand and gravel dust. Cement dust is composed mainly of lime, together with minor amounts of silica, alumina, and iron. Approximately 122 kilograms of cement dust are given off for each metric ton of cement produced and used.[1] A much smaller amount of sand and gravel dust, about 0.05 kilograms per metric ton, is produced.[2]

These dusts are given off in the process of manufacturing the concrete pilings. This process involves weighing, batching, and mixing raw materials, placing reinforcing rods in the form, pouring the concrete, and curing and finishing the product. This may be accomplished at a fixed plant (in the case of precast piling) or at the place of use (in the case of cast-in-place piling). Production also results in the release of sulfur dioxide and NOx emissions.

1/ Sittig, M., Pollution Control in the Asbestos, Cement, Glass, and Allied Mineral Industries, Park Ridge, N.J.: Noyes Data Corp., 1975, p. 103.

2/ Id., p. 146.

The primary source of water pollution from the concrete industry is the water used in washing the trucks and equipment.[1] This water raises the pH of natural waters, increases their turbidity, and reduces their dissolved oxygen content. It is not hazardous. It contains a variety of suspended solids derived from the raw materials of the concrete, plus a small amount of oil and grease. Total suspended solids and oil and grease are the two major pollutant parameters developed by EPA for the concrete products point source category.[2]

This information suggests that concrete piling is the best candidate, among those considered here, for replacing creosote-treated wood piling and reducing hazardous waste generation.

Parties Impacted by Substitution of Creosote-Treated Wood Piling By Concrete and Steel Piling

Analysis of the wood treatment industry suggests that the following parties will be impacted by this substitution:

1) suppliers of wood piling;
2) wood treatment sector;
3) users of treated wood piling; and
4) suppliers of substitute products.

Impact on Suppliers of Wood Piling

As mentioned at the outset of this chapter, the volume of treated pilings produced in 1979 was about 60 million cubic feet.

1/ Sitting, M., Pollution Control in the Asbestos, Cement, Glass, and Allied Mineral Industries, Park Ridge, N.J.: Noyes Data Corp., 1975, p. 308.

2/ EPA, Guidance Development Document Effluent Limitations Guidelines and New Source Performance Standards for Wood Products Point Source Category, EPA 440/1-78/090, pp. 4-5.

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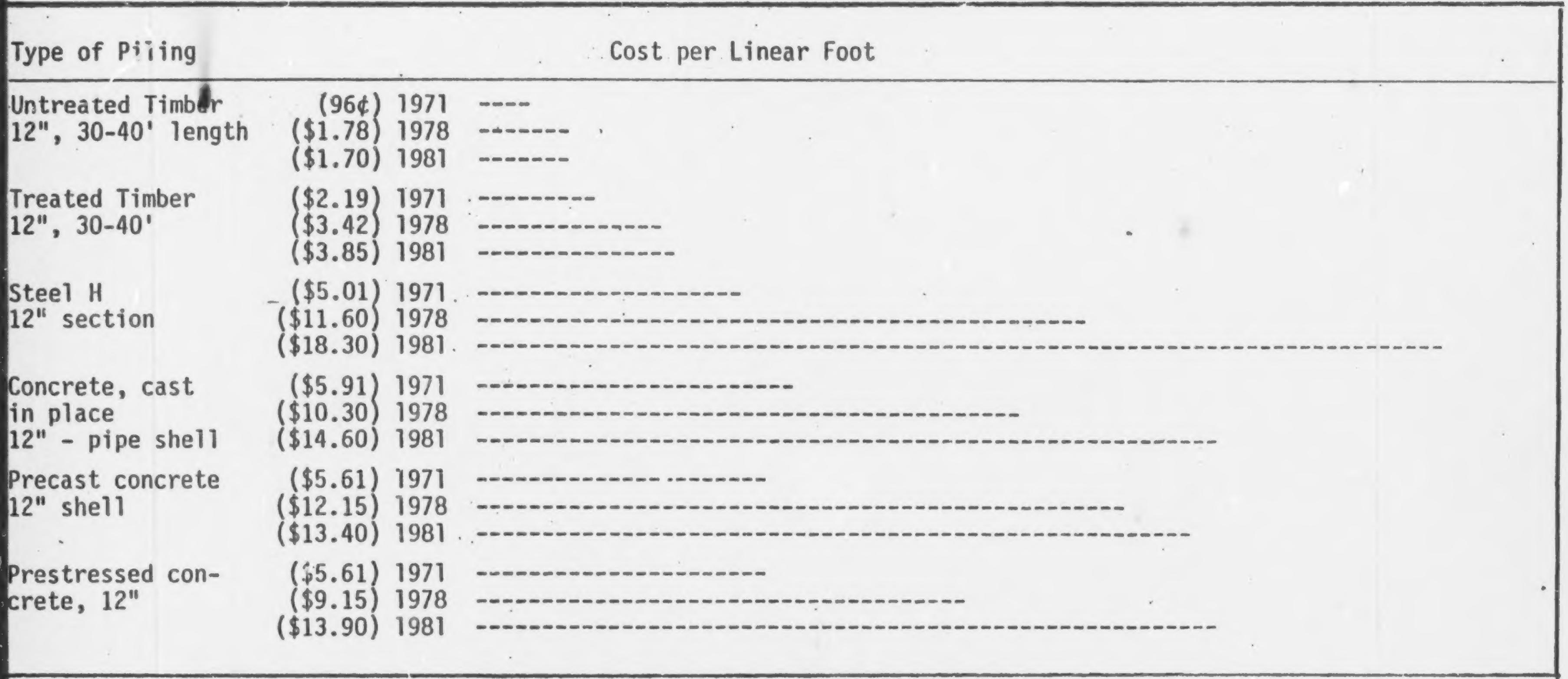
(See Table 30.) Thus, complete substitution of wood piling by other materials would reduce annual sales of wood products by about 6.1 million cubic feet. The value of 6.1 million cubic feet of piling and related wood products is difficult to estimate because of significant unit costs differences of wood products. Furthermore, the depressed construction industry has lowered prices of wood products, while the increases in oil prices have increased treatment costs and prices of various wood products. These counter trends may be considered to cancel each other, making the value of 6.1 million cubic feet of wood piling approximately $30 million, based on the price of $3.85 per linear foot found in Figure 9 . This value, however, does not represent loss to the lumber industry because wood used for piling may be readily converted to other uses. The specific proportion of wood piling which will be converted in other wood products is not possible to estimate, but certainly it will be large, because from a technical point of view all wood piling can be readily converted into other wood products. Thus, the impact of creosote treated wood piling substitution by other materials on the lumber industry will be negligible.

Impact on Wood Treatment Sector

Wood piling in 1979 represented about two percent of total wood products treated (Table 30.) Furthermore, the trends of wood piling as a proportion of all wood products treated by this sector has been declining over the last decade, as already noted. Industry sources indicate that as the result of this trend, the wood treatment industry has already adjusted to the loss of this segment of business. In summary, the impact of wood piling substitution by other materials on the wood treatment industry will be very small.

FIGURE 9

COMPARATIVE COSTS OF PILING



Type of Piling	Cost per Linear Foot	Year
Untreated Timber 12", 30-40' length	(96¢)	1971
	($1.78)	1978
	($1.70)	1981
Treated Timber 12", 30-40'	($2.19)	1971
	($3.42)	1978
	($3.85)	1981
Steel H 12" section	($5.01)	1971
	($11.60)	1978
	($18.30)	1981
Concrete, cast in place 12" - pipe shell	($5.91)	1971
	($10.30)	1978
	($14.60)	1981
Precast concrete 12" shell	($5.61)	1971
	($12.15)	1978
	($13.40)	1981
Prestressed concrete, 12"	($5.61)	1971
	($9.15)	1978
	($13.90)	1981

Note #1: The steel H and cast-in-place concrete piles are calculated for the conventional hammer. There is no apparent price difference if a vibratory hammer is used.

Note #2: The Steel H piles will cost 11¢ (1971) and 16¢ (1971 & 1978) per square foot more if the piles are coated with Bitumastic.

Source: McGraw-Hill's Dodge Guides. Editions 3, 10 and 13 (for the years 1971, 1978 and 1980 respectively). McGraw-Hill Information Systems Company, New York, NY.

Impact on Users

Impact of wood piling substitution on users of such piling will be significant because of the significant cost increase of substitute materials. As shown in Figure 9, steel and concrete piling costs three to five times as much as wood piling of the same dimensions. Of course, both steel and concrete pilings have much longer useful lives and therefore lifecycle costs for these pilings may be more comparable to the wood piling. Moreover, different sizes of substitutes may be used since a 12-inch steel H column may not be needed to replace a 12-inch wood piling; perhaps a smaller size would suffice. In general, however, users of wood piling will experience significant cost increases as the result of wood substitution by other materials.

Impact on Suppliers of Substitute Products

Substitution of wood piling by concrete and steel pilings will increase the demand for these products and therefore increase revenues of firms and sectors supplying steel and concrete piling. It is not possible to calculate the additional revenue resulting from this substitution exactly because specific configurations and therefore costs of steel and concrete piling to replace wooden piling depend on the specific applications. Note, however, that substitution of wood piling by concrete and/or steel results in longer useful life of a substitute or the possible use of substitutes with smaller cross-section, both of which may result in cost savings.

Conclusion

As in previous case studies, phenol-treated wood piling has several substitutes, the principal two being concrete and steel. Of these two, concrete piling is preferred from the point of view of environmental considerations because the use of this substitute generates significantly less waste. The manufacture of steel produces its own share of hazardous wastes, one of which is phenol.

Note, however, that the magnitude of phenol waste generation from the manufacture of steel is very small. Conversely, steel manufacture generates other hazardous wastes such as dissolved acids. There are no technical bars to substitution of wood piling, and if all of the wood piling would be replaced this would eliminate 50 thousand pounds of phenol wastes generated each year in the treatment of wood piling. However, steel piling is about five times as expensive as treated wood piling and concrete piling about three times as expensive.

On the other hand, both steel and concrete piling have considerably longer useful lives, and require smaller dimensions to carry the same loads. Our interviews with several engineering firms[1] indicate that the technological advantages of steel and concrete piling do not overcome the increased unit costs of these materials as compared to treated wood piling. Furthermore, the costs of concrete and steel piling have increased more rapidly than have the costs of wood piling (Figure 9). Therefore, as a rule, treated wood piling is used in most, if not all, applications unless the design and engineering considerations require steel and/or concrete piling.

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[1] Donohue and Sons; Western Engineering, Inc.

Therefore, treated wood piling substitution by concrete or steel piling is not likely to take place in the absence of appropriate regulations.

CHAPTER VI

SUBSTITUTION OF CFC IN SOLVENTS

The solvents product area encompasses almost all domestic applications of CFC-113 and does not involve substantial use of any other CFC.[1] Table 34 reports the distribution of CFC-13 among its various applications in 1976. By far the largest category of applications is cleaning and drying, which accounted for 84 percent of CFC solvent sales. The remaining uses of CFC-113 are described by DuPont as "solvent related" uses.

In cleaning, CFC-113 is used as an industrial solvent to remove flux from printed circuit boards and to clean scientific instruments or metal parts and assemblies.

Drying is a process similar to cleaning, with the solvent used to displace water. Drying equipment units share basic design and functional features with vapor degreasers.[2]

According to the Rand Study:

> Motives for using CFC-based solvents vary among cleaning applications. Some users have converted to CFC from other solvents, such as trichloroethylene which are believed to be hazardous to workers. Other users rely on the CFC because it is especially compatible with materials used in the final product, particularly plastics; the use of plastic components in many applications was permitted by the existence

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[1] The term CFC refers to chlorofluorocarbons, more specifically to chlorofluoromethanes $CF_xCl_yH_z$. There are about twenty-three (23) such compounds with very similar chemical compositions. CFC-113 represents one of the chlorofluorocarbons ethane series with chemical formulae such as $CClF_2ClF_2$ or CCl_2FCF_3.

[2] Rand Corporation, Economic Implications of Regulating Nonaerosol CFC Emissions, 1980, pp. 65-66.

TABLE 34

DOMESTIC SALES OF CFC-113 FOR CATEGORIES OF SOLVENT-RELATED USES, 1976

Use Category	Domestic Sales (millions of lbs.)	
Cleaning and drying (total)		55.2
Vapor phase cleaning:		
Defluxing	14.3	
Metal cleaning	3.6	
"Critical cleaning"	18.4	
Liquid phase cleaning:		
Open cleaning	6.6	
Closed systems	4.2	
Drying	3.7	
Government	4.4	
Dry Cleaning (total)		2.2
Other (total)		8.1
Chemical processing:		
Reaction Medium	1.2	
Intermediate	2.2	
Carrier medium	2.7	
Cutting fluid	1.6	
Miscellaneous	0.4	
Total		65.5

Source: E.I. DuPont de Nemours and Company, Information Requested by EPA on Non-aerosol Propellant Uses of Fully Halogenated Halocarbons, Wilmington, Delaware, March 15, 1978.

of CFC-113, which has been widely available since the early 1960's. Other attractive features of CFC solvent are that it is virtually nontoxic and photochemically nonreactive.

There are dozens of industrial solvents, which include many potential substitutes for CFC in cleaning applications. Among the substitutes most commonly noted are 1.1.1 trichloroethane (also known as methyl chloroform) and methylene chlorethane (also known as methyl chloroform) and methylene chloride. Recently, aqueous cleaners (systems using heated water sometimes deionized or with detergent additives) have made inroads in the solvent market, particularly for cleaning printed circuit boards. Crude data indicate that CFC-113 accounts for no more than five percent of the current total solvent market, but there may be submarkets in which the CFC is far more important. Industry sources argue, in particular, that CFC-113 is critical to the electronics and aerospace industries and that these industries account for the majority of CFC cleaning sales.

If the cleaning and drying market were to grow in step with projected growth in U.S. electronics production, CFC sales for cleaning and drying applications alone would reach 130 pounds in 1990. However, regulatory restrictions on other solvents found hazardous to worker health or to the environment could easily double the size of the CFC-113 market. Alternatively, market expansion could be inhibited through increased market penetration by aqueous cleaners or through improved solvent conservation.

There are currently three main classes of solvents used to dry-clean clothing. The CFC is mostly used in coin-operated units, where exposure to other solvents is deemed hazardous to the public, and for cleaning specialty goods, such as leathers. The other two classes of dry cleaning agents, petroleum solvents and perchloroethylene, are both under investigation for impending regulation.

DuPont and Allied offered somewhat different projections of future domestic market growth. The two sets of estimates were combined to yield the "industry projections" shown in Table 35. For the first four years, the average annual growth rate for nonrefrigerant sales is higher (8 percent) than for the succeeding years (5 percent). These results are similar to those that would be obtained if CFC-113 sales were to grow at the rate projected for electronics industry production.

Five U.S. companies currently manufacture CFCs but only DuPont and Allied produce CFC-113.[1]

As far as can be determined, similar production processes are used by all the manufacturers.[2] The pairs CFC-11/CFC-12 and CFC-113/CFC-114 are co-produced; plants designed for the production of one pair cannot readily be converted to production of the other pair.

CFC-113/CFC-114 production data is not as readily available as that for the other CFCs. Table 36 shows CFC-113 production and sales as estimated by Rand.[3] For purposes of this study, the Rand estimates will be adopted since they derived from recent conversations with industry sources and therefore should be reliable.

1/ Penwalt and Union Carbide formerly produced CFC-113.

2/ Although the same chemical equations apply for CFC manufacture, the process conditions may vary from producer to producer.

3/ Rand Corporation, *Economic Implications of Regulating Nonaerosol CFC Emissions*, 1980.

TABLE 35

INDUSTRY PROJECTIONS OF DOMESTIC PRODUCTION AND SALES OF CFC-113 SOLVENT, 1976 to 1990 (Millions of pounds)

Year	Domestic Production	Exports	Imports	Domestic Sales
1978	87	4	--	83
1979	94	4	--	90
1980	101	5	1	97
1981	106	5	1	102
1982	110	5	2	107
1983	116	6	2	112
1984	121	6	3	118
1985	126	6	4	124
1986	132	6	4	130
1987	138	7	5	136
1988	144	7	6	143
1989	151	8	7	150
1990	158	8	8	158

Source: Calculated from data supplied by DuPont and Allied Chemical. Refrigeration uses of CFC-113 are omitted.

TABLE 35

DOMESTIC PRODUCTION, DOMESTIC AND EXPORT SALES OF CFC-113, 1970 to 1977

(Millions of pounds)

Year	Production	Domestic Sales	Export Sales
1970	41	39	2
1971	42	40	2
1972	49	47	2
1973	65	62	3
1974	69	66	3
1975	63	60	3
1976	69	66	3
1977	81	77	4

Source: Computations performed by Rand from data provided by the two CFC-113 producers, DuPont and Allied Chemical. Refrigerant applications are excluded from all data.

Note: Imports of less than 500,000 pounds per year are omitted from domestic sales.

Hazardous Wastes Generated

Emissions of CFC-113 in production have been described as very small.[1] Producers estimate that about two percent of the product sold is emitted during packaging and transportation to users.[2] Following delivery to users in cleaning and drying applications, some solvent escapes in vapor form from the tank or the surface of articles removed from the tank. The remainder is removed when the tank is drained for cleaning and evaporates, is sealed in drums and buried, or is reclaimed for reuse. In dry cleaning, the CFC-113 escapes into the atmosphere from residues in cleaned clothing or from equipment filters. According to the EPA, between 69 and 70 million pounds of CFC-113 were emitted in 1977.[3] This was the culmination of a steady increase in total CFC-113 emissions since at least 1970, when emissions were estimated to be between 35 and 39 million pounds.

Effects of Substitutions on Hazardous Waste Reduction

There is a wide range of solvents currently available which could be used as substitutes for CFC-113. As was the case with other substitutions discussed earlier, some substitutes are better in particular applications than others.

Among the most prominent of the substitutes are carbon tetrachloride, chloroform, carbon disulfide, methylchloroform (also known as 1,1.1 trichloroethane), hydrofluoric acid, methylene chloride, perchloroethylene, and various aqueous cleaners. According to an EPA-sponsored study, every substitute solvent has some known or suspected risk associated with its use. Included in these risks are hazards to the health of workers, contributions to photochemical smog, and pollution of waterways. For example, carbon tetrachloride, carbon disulfide, chloroform, hydrofluoric acid, perchloroethylene, and methylchloroform are all listed as hazardous wastes. Thus, there is currently little incentive to substitute other solvents for CFC-113 since this would amount to little more than substituting one evil for another. Moreover, while CFC-113 prices have risen sharply in recent years (increasing by 30 percent between 1970 and 1977), the prices of potential substitutes have doubled during the same interval.[1] Thus, the economic incentive to continue to use CFC-113 is very much present.

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[1] EPA, Economic Implications of Regulating Chlorfluorocarbon Emissions from Nonaerosol Applications, EPA-560/12-80-001, October 1980, p. 70.

[2] Id.

[3] Id., p. 71. Note that about 66 percent of these emissions are absorbed in cyclones and/or filters and become waterborne wastes or solid wastes. This means that in 1977 between 45.5 and 46.2 million pounds of CFC-113 were generated as hazardous wastes.

Parties Impacted by Substitutions

CFC-113 substitution will have marginal impact on users of this solvent, due to the availability of a wide range of substitutions. Manufacturers of CFC-113 will not be impacted to a large extent by CFC-113 substitution. This is the case because CFC-113 production facilities may be used for the manufacture of substitutes. Note, however, that CFC-113 production represents 16 percent of total CFC-113 production for Allied and 13 percent of total CFC production for DuPont. Of the total CFC-113 sales in 1977, Allied's share was 33 percent and DuPont's was 67 percent.[1]

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[1] EPA, *Economic Implications of Regulating Chlorflurocarbon Emissions from Nonaerosol Applications*, EPA-560/12-80-001, October 1980, p. 80.

The values of sales for CFC-113 are unavailable. Table 37 gives estimates of historical CFC-113 bulk prices for the 1970-1977 period. Use of these bulk prices will almost certainly lead to an underestimation of sales values. Nevertheless, the 1977 CFC-113 price of 56 cents per pound results in a 1977 CFC-113 sales value of 44.8 million dollars.

Table 38 shows the allocation of the 1977 sales for the CFC-113 to each producing firm. The values were derived by assuming that sales value can be apportioned according to the portion of capacity held by each producer.

In summary, substitution of CFC-113 in use as solvent will decrease annual revenues of the two producers of CFC-113 by less than one-half of one percent, a magnitude which can not be considered significant.

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[1] Rand Corporation, *Economic Implications of Regulating Nonaerosol CFC Emissions*, 1980.

TABLE 37

CFC-113 HISTORICAL PRICES -- 1970-1977

Year	CFC-113
1970	40
1971	40
1972	40
1973	38.4
1974	43.3
1975	48.5
1976	52
1977	56

Source: Rand Corporation, *Economic Implications of Regulating Nonaerosol CFC Emissions*, 1980.

TABLE 38

CFC-113 SALES, 1977
(millions of dollars)

Producer	CFC-113 Sales	Total CFCs Sales	Total Sales
Allied	15.0	79.9	2922.8
DuPont	30.4	198.7	9434.8
Total	45.4	278.6	12,357.6

Source: Rand Corporation, *Economic Implications of Regulating Nonaerosol CFC Emissions*, 1980.

Conclusion

As in previous case studies, there are a number of substitutes for CFC-113. As a matter of fact, there are over ten such substitutes. However, note that none of these substitutes can substitute for CFC-113 in all applications. The economic impact of CFC-113 substitution is not significant. While the annual sales of CFC-113 are relatively large, i.e., about $45 million, the manufacturing processes used for production of CFC-113 can be readily adopted for the production of most, if not all, substitute end-products.1/ Thus, it is reasonable to expect that if there would be significant substitution of CFC-113 by other end products, the principal manufacturers of CFC-113 (Allied and DuPont) would react in the face of the declining demand by switching to the production of adjusting CFC-113 manufacturing processes for the production of substitutes.

Because all of the substitutes for CFC-113 have similar chemical and physical characteristics, the use of these substitutes in place of CFC-113 will not require significant changes in the equipment nor in operating procedures by the users of CFC-113.

The costs of substitutes for CFC-113 and the cost differentials are somewhat increasing and this will have an impact on the current

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1/ This is the case, according to our interviews with chemical industry executives, with most organic chemical compounds. Interviews with Clark A. Kibler, Senior Staff Engineer, Allied Chemical Corporation.

users of CFC-113. The principal issue with the substitutes for CFC-113 is that every technically appropriate substitute has certain environmental and/or occupational hazards associated with its use and therefore represents only a marginal improvement with respect to hazards over the use of CFC-113.

Note, however, that a complete scientific investigation on the hazards associated with CFC-113 and with the substitute products is not as yet completed,[1/] and therefore policy decisions as to which of the CFC-113 substitutes represents the lesser of the evils can not be made with certainty at this time.

[1/] Interview with Emery Lazar, EPA.

CHAPTER VII

AN EXAMPLE OF UNSUCCESSFUL END-PRODUCT SUBSTITUTION

This chapter presents a review of an unsuccessful attempt to modify or substitute end-products for the purpose of reducing generation of hazardous wastes. Specifically, this chapter examines the attempts at finding substitutes for asbestos in friction materials.

Friction materials are used in practically all industries as a key component in clutches for transmitting torque, brakes for slowing down or stopping motion, or as torque limiters. Many raw materials, including some whose exact roles are regarded as proprietary knowledge, are used in varying quantities in the manufacture of friction materials. The major, or foundation constituent, of practically all organic friction materials is asbestos fiber. The asbestos usually used in friction materials is chrysotile from Quebec or Vermont. Asbestos is an important ingredient in these friction material products because it imparts strength, has good friction properties, can withstand high temperatures, and is a good insulator. Although friction applications in passenger automobile brakes and clutches are the most important commercially, asbestos-friction applications are not limited to automobiles. Rather, these applications are found wherever motions must be controlled, and include trucks, buses, construction equipment, railroad cars, farm tractors, presses, hoists, tensioning devices in production of wire and plastic rope and cable, lift trucks, machine tools, shuttlecars, specialized mining equipment, x-ray machines, wheel brakes, tape recorders, typewriters, bicycle brakes, snowblowers and washing machines.

U.S. demand for asbestos in friction products has been about sixty-five thousand tons annually from 1967 to 1976. This amounts to approximately 9 percent of the total U.S. asbestos demand (consumption). Principal U.S. manufacturers of asbestos friction products are shown in Table 39.

Manufacturing Processes and Sources of Asbestos Emissions

The principal processes used in the manufacture of asbestos friction materials are described below for the principal types of such products. In addition to a variety of steps such as molding or baking, each of these processes typically involves materials mixing steps and product finishing steps such as sanding, grinding, drilling, and cleaning. These mixing and finishing steps are the primary sources of hazardous waste generation in the manufacture of asbestos friction materials.

The manufacturing steps typically performed in dry-mix molded brake lining manufacture are shown in Figure 10. The bonding agents, metallic constituents, asbestos fibers, and additives are weighed and mixed in a two-stage mixer. The mix is then handstamped into a metal mold. The mold is placed in a preforming press which partially cures the molded asbestos sheet. The asbestos sheet is taken from the performing press, and put in a steam preheating mold to soften the resin in the molded sheet. The molded sheet is formed to the proper arc by a steam-heated arc former,

TABLE 39

U.S. MANUFACTURERS OF ASBESTOS-BEARING FRICTION MATERIALS

Company	Plant Location	Estimated 1975 Sales of Friction Materials ($ million)
Raybestos-Manhattan, Inc.	Stratford, Conn. Mannheim, Pa. Crawfordsville, Ind. Fullerton, Calif.	110.0
Bendix Corporation	Troy, N.Y. Cleveland, Tenn.	72.5
Abex Corporation	Cleveland, Ohio Troy, Michigan American Brakeblok Division Winchester, Va.	60.1
General Motors Corp.	Delco-Moraine Div. Dayton, Ohio Inland Division Dayton, Ohio	30.0
H.K. Porter Co.	Huntington, Indiana Richmond, Ky.	26.0
Chrysler Corporation	Cycleweld Division Trenton, Michigan	—
Borg Warner Corporation	Spring Division Bellwood, Ill.	—
World Bestos Co.	New Castle, Ind.	18.8
National Friction Products Corp.	Logansport, Ind.	10.2
Gatke Corporation	Warsaw, Ind.	10.0
Carlisle Corporation	Ridgeway, Pa.	9.7
Maremont Corporation	Grizzly Products Division Paulding, Ohio	8.7

TABLE 39. U.S. MANUFACTURERS OF ASBESTOS-BEARING FRICTION MATERIALS (Cont'd

Company	Plant Location	Estimated 1975 Sales of Friction Materials ($ million)
Scandura, Inc.	Charlotte, N.C.	----
Mar Pro Corporation	Grizzly Brake Division Chicago, Ill.	----
Standco Industries	Houston, Texas	8.7
Forcee Mfg. Corporation	Tappahannock, Va.	----
Royal Ind. Brake Products, Inc.	Danville, Ky.	5.7
Auto Friction Corp.	Lawrence, Ma.	5.7
L.J. Miley Co.	Chicago, Ill.	5.5
Friction Products Co.	Medina, Oh.	4.0
United States Brake Lining Corp.	Miami, Fla.	2.9
Brassbestos Mfg. Corp.	Patterson, N.J.	1.7
Southern Friction Material Co.	Charlotte, N.C.	----
Reddaway Mfg. Co.	Newark, N.J.	1.7
Molded Ind. Friction Corp.	Prattville, Ala.	----
Auto Specialties Mfg. Co.	St. Joseph, Mich.	----
Lasco Brake Products Co.	Oakland, Calif.	<1
California Blok Co.	Gardena, Calif.	<1
MGM Brakes, Inc.	Cloverdale, Calif.	<1
Wheeling Brake Block Mfg. Co.	Wheeling, W.Va. Bridgeport, Ohio	<1

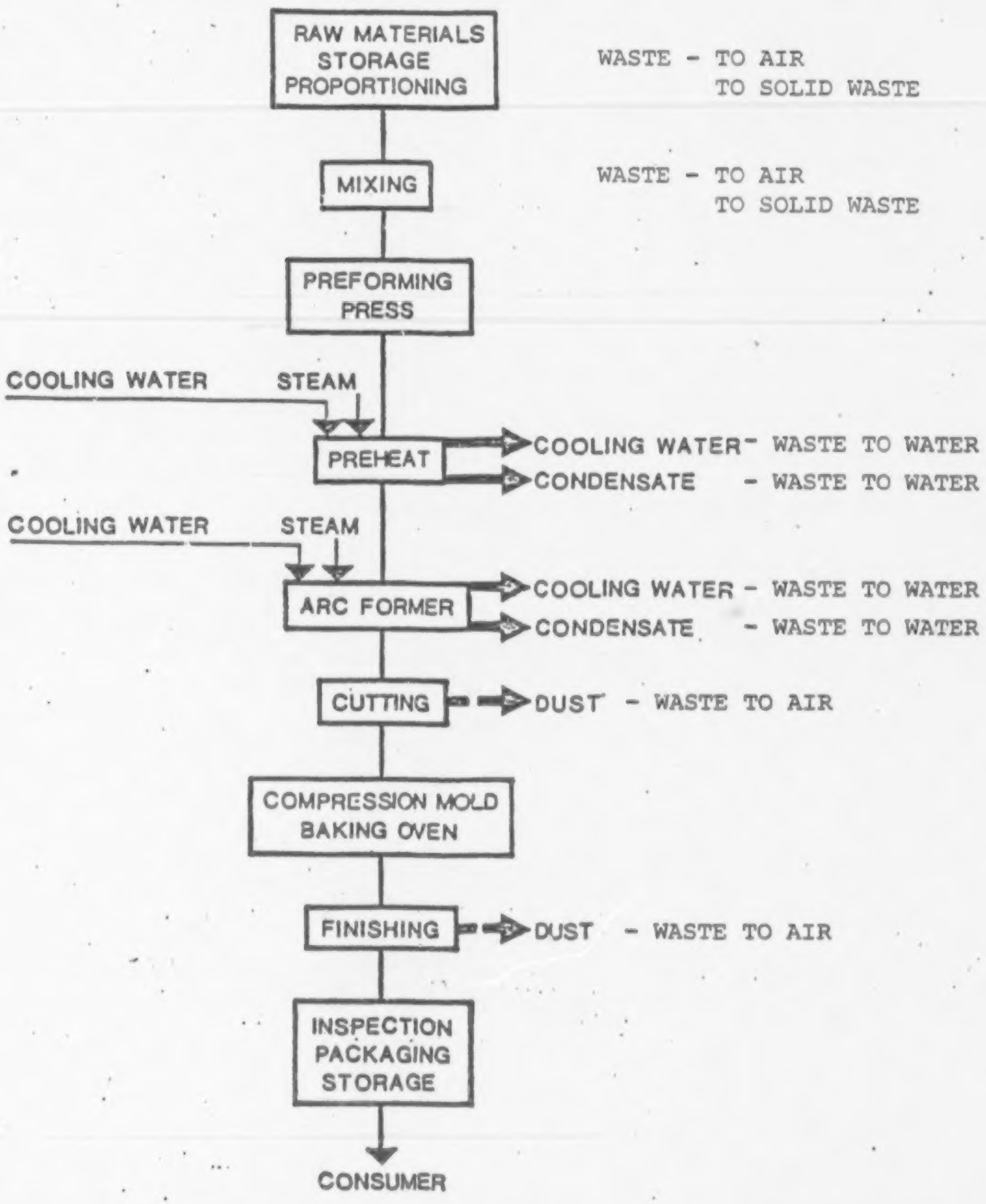
TABLE 39: U.S. MANUFACTURERS OF ASBESTOS-BEARING FRICTION MATERIALS (Cont'd

Company	Plant Location	Estimated 1975 Sales of Friction Materials ($ million)
Baldwin-Ehnet Hill, Inc.	Trenton, N.J.	<1
Thiokol Chemical Corp.	Trenton, N.J.	<1
P.T. Brake Lining Co.	Lawrence, Mass.	----
Hunt/Airheart Products, Inc.	Chatsworth, Cal.	----
Re-Bilt Auto Products Corp.	Brooklyn, N.Y.	----

SOURCE: W.M. Meylan, et al., Chemical Market Input/Output Analysis of Selected Chemical Substances to Assess Sources of Environmental Contamination: Task III. Asbestos, for EPA, Washington, D.C., 1978.

FIGURE 10

DRY-MIXED BRAKE LINING MANUFACTURING OPERATIONS


RAW MATERIALS STORAGE PROPORTIONING
WASTE - TO AIR
TO SOLID WASTE
MIXING
WASTE - TO AIR
TO SOLID WASTE
PREFORMING PRESS
COOLING WATER
STEAM
PREHEAT
COOLING WATER - WASTE TO WATER
CONDENSATE - WASTE TO WATER
COOLING WATER
STEAM
ARC FORMER
COOLING WATER - WASTE TO WATER
CONDENSATE - WASTE TO WATER
CUTTING
DUST - WASTE TO AIR
COMPRESSION MOLD BAKING OVEN
FINISHING
DUST - WASTE TO AIR
INSPECTION PACKAGING STORAGE
CONSUMER

SOURCE: W.M. Meylan, et al., Chemical Market Input/Output Analysis of Selected Chemical Substances to Assess Sources of Environmental Contamination: Task III. Asbestos, for EPA, Washington, D.C., 1978.

which resets the resin. The arc-formed sheets are then cut to the proper size. The lining is then baked in compression molds to retain the arc shape and convert the resin to a thermoset or permanent condition. The lining is then finished and, after inspection, is packaged. The finishing steps include sanding and grinding of both sides to correct the thickness, edge grinding, and drilling of holes for rivets. Following drilling, the lining is vacuum-cleaned, inspected, branded, and packaged.

Figure 11 shows the major steps in the manufacture of wet-mixed molded brake linings. The name "wet mix" process is a misnomer and refers to the use of a solvent. The ingredients of the molded lining are actually relatively dry. After weighing, they are mixed and then sent to grinding screens where the particle size of the mixture is corrected. The mixture is conveyed to a hopper and is forced from the hopper into the nip of two form rollers which compress the mixture into a continuous strip of friction material. The strip is cut into the proper lengths and then arc-formed on a round press bar. The cutting and arc forming operations are done by separate units. The linings are then placed in racks and either air-dried or oven-dried to remove the solvent. An alternative process is to place the arc-formed linings in metal molds for baking in an oven. From the ovens, the linings are finished, inspected, and packaged.

Molded clutch facings are produced in a manner similar to the wet-mixed process. The rubber friction compound, solvent, and asbestos fibers are introduced into a mixer churn. After the

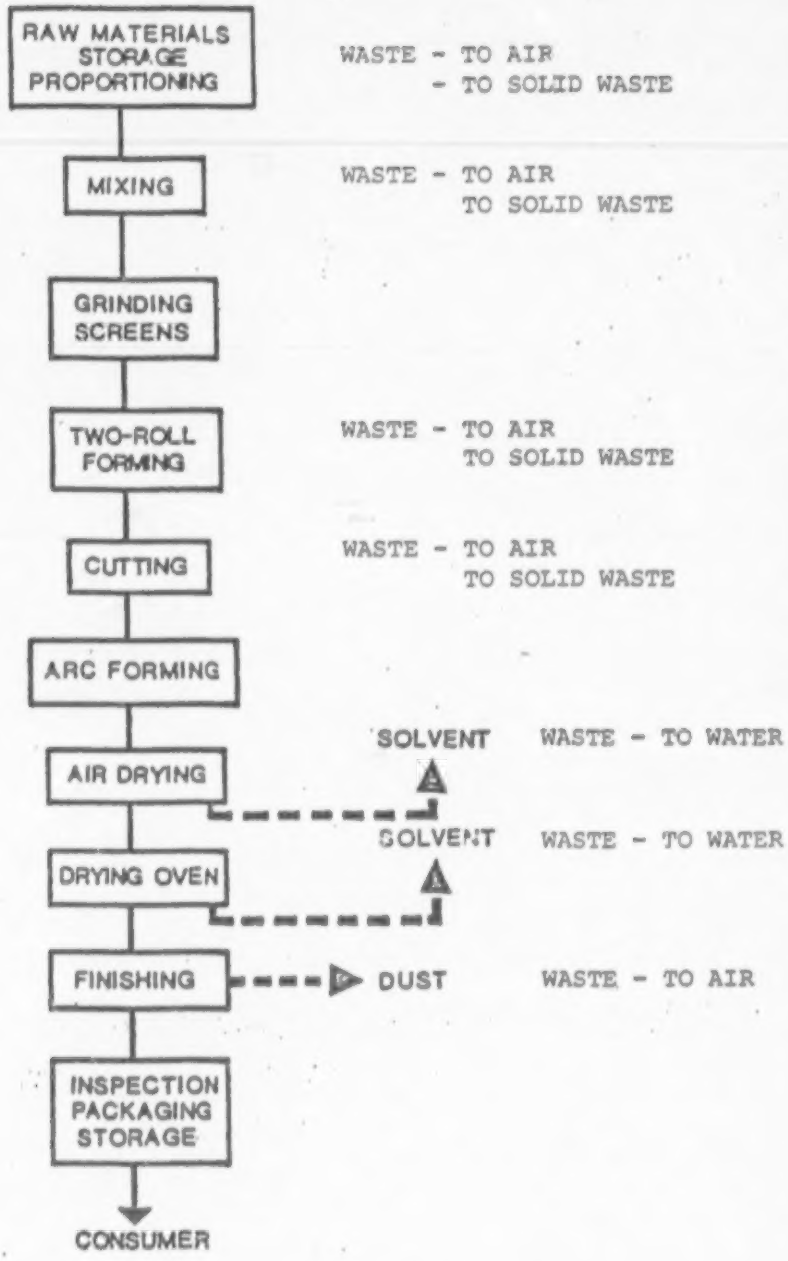

RAW MATERIALS
STORAGE
PROPORTIONING
WASTE - TO AIR
- TO SOLID WASTE
MIXING
WASTE - TO AIR
TO SOLID WASTE
GRINDING
SCREENS
TWO-ROLL
FORMING
WASTE - TO AIR
TO SOLID WASTE
CUTTING
WASTE - TO AIR
TO SOLID WASTE
ARC FORMING
AIR DRYING
SOLVENT
WASTE - TO WATER
DRYING OVEN
SOLVENT
WASTE - TO WATER
FINISHING
DUST
WASTE - TO AIR
INSPECTION
PACKAGING
STORAGE
CONSUMER

FIGURE 11: Wet-Mixed Molded Brake Lining Manufacturing Operations

SOURCE: W. M. Meylan, et al., Chemical Market Input/Output Analysis of Selected Chemical Substances to Assess Sources of Environmental Contamination: Task III. Asbestos, for EPA, Washington, D.C., 1978.

churn mixes the ingredients, the mixture is conveyed to a sheeter mill which forms a sheet or slab of the materials. The sheet is then diced into small pieces by a rotary cutter. The pieces are placed in an intrusion machine which forms sheets of the diced material. The sheets are cut into the proper size and then punch-pressed into doughnut-shaped sheets. The scraps from the punch press are returned to the extrusion machine. The punched sheets are placed on racks and sent to a drying oven and then a baking over for final curing and solvent evaporation. The oven-dried sheets are finally sent to the finishing operations. Figure 12 illustrates the steps in the manufacture of molded clutch facings.

Woven clutch facings and brake linings are manufactured of high-strength asbestos fabric that is frequently reinforced with wire. The fabric is predried in an oven or by an autoclave to prepare it to be impregnated with resin. The fabric can be impregnated with resin by several techniques: 1) immersion in a bath of resin, 2) introducing the binder in an autoclave under pressure, 3) introducing dry impregnating material into carded fiber before producing yarn, and 4) imparting binder into the fabric from the surface of a roll. After the solvents[1/] are evaporated from the fabric, it is made into brake linings or clutch facings. Brake linings are made by calendering or hot pressing the fabric in molds. The linings are then cut, rough ground, placed in molds, and placed in a baking oven for final curing.

[1/] Which may or may not be recyclable depending on the advancement of the manufacturing technology used with more advanced processers utilizing recycling of the solvents.

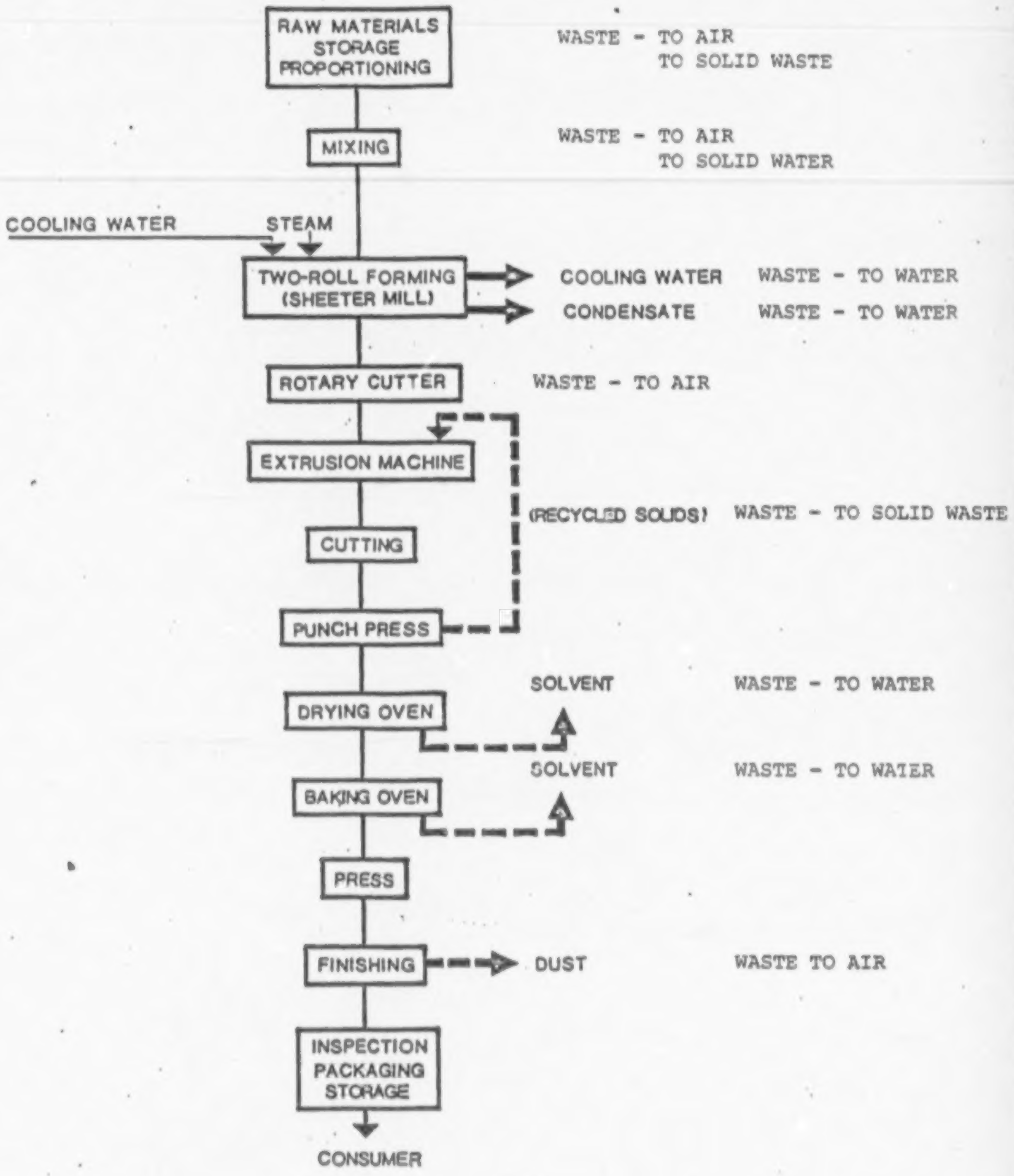

RAW MATERIALS STORAGE PROPORTIONING
WASTE - TO AIR
TO SOLID WASTE
MIXING
WASTE - TO AIR
TO SOLID WATER
COOLING WATER
STEAM
TWO-ROLL FORMING (SHEETER MILL)
COOLING WATER
WASTE - TO WATER
CONDENSATE
WASTE - TO WATER
ROTARY CUTTER
WASTE - TO AIR
EXTRUSION MACHINE
(RECYCLED SOLIDS)
WASTE - TO SOLID WASTE
CUTTING
PUNCH PRESS
SOLVENT
WASTE - TO WATER
DRYING OVEN
SOLVENT
WASTE - TO WATER
BAKING OVEN
PRESS
FINISHING
DUST
WASTE TO AIR
INSPECTION PACKAGING STORAGE
CONSUMER

FIGURE 12: Molded Clutch Facings Manufacturing Operations

SOURCE: W.M. Meylan, et al., Chemical Market Input/Output Analysis of Selected Chemical Substances to Assess Sources of Environmental Contamiation: Task III. Asbestos, for EPA, Washington, D.C., 1978.

Following curing, the lining is finished, inspected, and packaged. The composition by weight of woven brake linings ranges from 40 to 60 percent asbestos, 10 to 20 percent cotton, 20 to 40 percent wire, and 5 to 20 percent binder.

Figure 13 illustrates the manufacture of woven clutch facings. The treated fabric is cut into tape-width strips by a slitting machine. The strips are wound around a mandrel to form a roll of the fabric. The roll is pressed in a steam-heated press and then baked in an oven to cure the resin in the clutch facing. Following curing, the clutch facing is finished, inspected, and packaged.

Quantities of Asbestos Released to the Environment From Manufacture

Listed below in Table 40 are the estimated quantities asbestos released to the environment from asbestos friction products manufacture. They total over 7,300 metric tons per year, and represent about a sixth of the total asbestos releases from all manufacturing.[1/] The estimates in Table 40 are not intended to be considered precise quantities. They are based upon available data and engineering assumptions and are intended only to project a general magnitude of release.

Shipment Trends

The value of asbestos friction materials in commerce is considerable. In 1977, for example, it approached 300 million dollars. The trend in the value of shipments of asbestos friction materials is shown in Table 41. Between 1972 and 1977, the value of shipments increased 42 percent. During the five year period from 1967 to 1972,

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[1/] See Table 15.

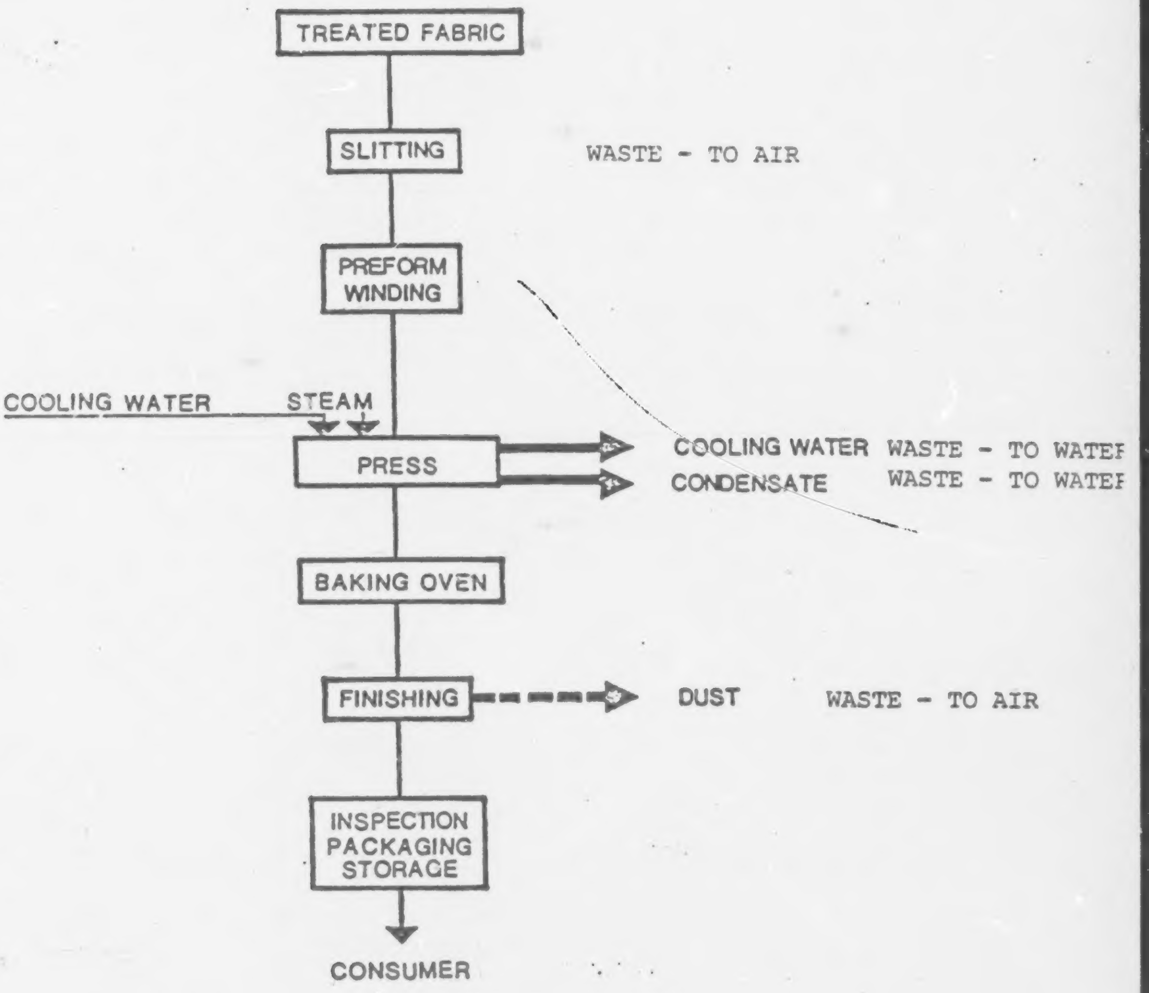
TREATED FABRIC
SLITTING
WASTE - TO AIR
PREFORM WINDING
COOLING WATER
STEAM
PRESS
COOLING WATER
WASTE - TO WATEF
CONDENSATE
WASTE - TO WATEF
BAKING OVEN
FINISHING
DUST
WASTE - TO AIR
INSPECTION PACKAGING STORAGE
CONSUMER

FIGURE 13: Woven Clutch Facings Manufacturing Operations

SOURCE: W.M. Meylan, et al., Chemical Market Input/Output Analysis of Selected Chemical Substances to Assess Sources of Environmental Contamination: Task III. Asbestos, for EPA, Washington, D.C., 1978.

TABLE 40

ESTIMATED ANNUAL ENVIRONMENTAL RELEASE OF ASBESTOS FROM FRICTION MATERIAL MANUFACTURE

	Quantity (metric tons)	Comment
To waste dump or landfill:		
Baghouse fine and product scraps	7,317	Mostly free-fibers*
Wastewater solids from air scrubbers	6.0	Wet free-fibers*
To water:		
Wastewaters from air scrubbers	0.3	Free-fibers*
To air:		
Baghouse emissions	0.55-5.4	Free-fibers*
Air scrubber emissions	0.13	Free-fibers*

* These "free-fibers" may be coated with resin; however, by "free" the intention is to indicate a potentially respirable fiber.

SOURCE: W.M. Meylan, et al., Chemical Market Input/Output Analysis of Selected Chemical Substances to Assess Sources of Environmental Contamination: Task III. Asbestos, for EPA, Washington, D.C., 1978.

TABLE 41

Value of Shipments of Asbestos Friction Materials

SIC Product Code	Product	Total Product Shipments, including interplant transfers (millions dollars)			
		1977	1972	1967	1963
32922 --	Asbestos Friction Materials - Total	297.2	209.5	144.4	177.7
	Brake Linings:				
32922 11	Woven, containing asbestos yarn, tape, or cloth	17.1	10.2	13.5	---
32922 15	Molded, including all non-woven types	126.0	113.1	95.6	---
32922 21	Disc Brake Pads	18.2	14.2	---	---
	Clutch Facing:				
32922 51	Woven, containing asbestos yarn, tape, or cloth	72.0	19.9	17.2	---
32922 55	Molded, including all non-woven types	57.1	48.5	16.1	---
32922 00	Asbestos Friction Materials, n.s.k.	6.8	3.6	2.0	---

Source: 1977 Census of Manufacturers

shipment values increased by 45 percent as compared to an 18 percent decrease for the four year period from 1963 to 1967.

Table 41 also gives a breakdown for the major asbestos friction material products. In 1977, brake linings accounted for over 48 percent of shipment values while clutch facings accounted for over 43 percent of the shipment values. If disc brake pads are included along with brake linings, then asbestos brake materials account for 54 percent of the total value of asbestos-friction materials. The industry is quite concentrated, with the top eight producers accounting for 85 percent of industry's value of shipments.1/

Availability of Substitutes

Any alternative material to asbestos in brake linings has to compete with asbestos' properties of strength, high temperature protection, insulation and good frictional properties.2/

Alternatives in Drum Brake Pads

At this time there are no commercially available asbestos-free brake linings intended for use in automobiles with drum brakes. However, nearly all of the major brake lining manufacturers are engaged in research and testing programs to develop asbestos-free drum brake linings for automobiles; limited commercial success has been achieved only with semimetallic friction material.

1/ See: W.M. Meylan, et al., Chemical Market Input/Output Analysis of Selected Chemical Substances to Assess Sources of Environmental Contamination: Task III. Asbestos, for EPA, Washington, D.C., 1978, p. 10; and Margolin, S.V. and Igwe, B.U.N., "Economic Analysis of Effluent Guidelines: The Textile, Friction and Sealing Materials Segment of the Asbestos Manufacturing Industry", U.S. Nat. Tech. Inform. Service (NTIS), PB-25-682, 1975.

2/ Hatch, D., "Possible Alternatives to Asbestos as a Friction Material", Ann. Occup. Hyg. 13, 25-29, 1970.

The possible asbestos alternatives which are being tested and considered are discussed below:[1]

(1) Glass Fiber - overall strength is lower than that of asbestos, but strong enough for friction material applications. Unfortunately, at the temperatures reached by braking operations, glass fiber melts, even in depths below the operating surface.

(2) Steel Wool - compared to asbestos, the overall strength is lower and the cost is much higher. In addition, the material hardness of steel wool damages the brake drums.

(3) Mineral Wools - overall strength is very low and brittle to the extent of limiting mixing processes.

(4) Carbon Fiber - the main properties of carbon fibers are generally good, but still inferior to asbestos. A major consideration is the cost, which is a great deal more than asbestos.

(5) Sintered Metals and Cement - these materials are now being used to manufacture brake linings for railroad cars and airplanes. Eventually, these materials may be developed into practical applications for automobiles. At this time the wear-resistance is not good enough for automotive uses and the cost is too high.

Alternatives in Disc Brake Pads

The friction materials used in disc brakes are designed to a stronger shape than in drum linings; that is, more or less square or circular pads of considerable thickness are supported by a metal plate of adequate thickness. Therefore, the friction material does not have to stand up to handling during assembly, does not have to withstand riveting and, could, from the point of view of bulk mechanical strength alone, be made without a high loading of fibrous reinforcement of any kind. There remains, however, thermal shrinkage and thermal shock, and in order to present the formation of tensile cracks normal to the operating surface, a percentage of asbestos fiber is still retained.[1/]

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[1] W.M. Meylan, et al., Chemical Market Input/Output Analysis of Selected Chemical Substances to Assess Sources of Environmental Contamination: Task III. Asbestos, for EPA, Washington, D.C., 1978, p. 100.

Nevertheless, it cannot be said that the use of asbestos in disc brake pads remains a technical necessity;[2/] in fact, commercially available disc pads have been developed for automotive uses which do not use asbestos. Table 42 lists a typical composition for this asbestos-free disc pad. Cost of the asbestos-free pad is somewhat higher than the asbestos pad.

Alternatives in Clutches

Borg-Warner Corporation, a major manufacturer of clutches, is currently engaged in the testing of asbestos-free friction materials intended for use in clutches. The asbestos-free materials being tested have been developed by the major friction-material producers such as Raybestos-Manhattan and Abex. To date, none of the alternatives tested have been as good as asbestos.

Reasons for Failure for Substitution

The attempt to find substitutes for asbestos in friction materials has largely been a failure to date. The reasons for this failure are illustrative of the difficulties inherent in attempts to substitute one product for another for the purpose of reducing the generation of hazardous wastes.

1/ Hatch, D., "Possible Alternatives to Asbestos as a Friction Material", Ann. Occup. Hyg., 13, 25-29, 1970.

2/ Hatch, D., op. cit.

TABLE 42

ASBESTOS-FREE COMPOSITION OF A DISC BRAKE PAD

	(vol. %)
Carbon	45
Iron Powder	25
Steel Fiber	10
Phenolic Resin	20

SOURCE: W.M. Meylan, et al., Chemical Market Input/Output Analysis of Selected Chemical Substances to Assess Sources of Environmental Contamination: Task III. Asbestos, for EPA, Washington, D.C., 1978.

In a nutshell, there are two reasons why substitution has failed in this instance: the unique physical qualities of the product for which substitution is sought, and the economic unattractiveness of even marginally suitable alternatives.

Note that the attempts to develop a substitute for asbestos in friction materials have not focused on finding one substitute suitable for all existing friction material uses for asbestos. Instead, efforts have been directed toward a viable substitute for each of the various end uses individually. Thus the asbestos friction materials case is a classic example of the approach ordinarily required in end-product substitution. A variety of substitutes are required. This is not surprising since if an economically and technologically acceptable material were available for across-the-board substitution, chances are it would already be competing with the hazardous waste producing material presently in use.

This chapter has repeatedly stressed that asbestos has special qualities of strength, friction, high temperature tolerance, and insulation. The discussion of alternatives in drum brake pads shows how substitutes are able to meet some of these qualities, but fail to meet others in all cases. The same is true of discussion of alternatives in clutches. Note, however, that as to disc brake pads, a technologically suitable substitute has apparently been found, at least in part because disc brakes do not require the full range of qualities which so far mandates the use of asbestos in the other friction materials application.

Despite the technological availability of a substitute in the disc brake pad case, cost still constrains the substitution. Asbestos is a relatively plentiful material which is easily produced, transported, and worked. As such it is inexpensive compared to potential substitutes. Cost thus is a factor which constrains the development of substitutes for asbestos in friction materials. As shown in the discussion of drum brake pad alternatives, the substitutes whose physical properties make them the most promising are also the most costly. Accordingly, there is no market incentive to use these substitutes. Any manufacturer using them would be at a competitive disadvantage, at least as to pricing, to other manufacturers who continue to use asbestos in competing products.

This shows that physical properties and cost combine to discourage the development of substitute end products in some cases. Nevertheless, continued research may show that there does exist an end-product whose properties and cost are such that it can be a true substitute for an end-product whose manufacture, use, or disposal generates hazardous wastes.

CHAPTER VIII

CONCEPTUAL MODEL FOR END PRODUCT SUBSTITUTION FEASIBILITY ANALYSES

Introduction

This chapter presents a conceptual model for end-product substitution feasibility analysis. The overall objective of such a model is to allow for a determination of The feasibility of substituting one end-product for another end-product, in the event manufacture and/or use of an end-product generates hazardous wastes.

The term "feasible" is a crucial one and requires elaboration. As noted elsewhere in this report,[1] end-product substitution is commonplace and occurs with some frequency, but most of it is motivated by economic (profit) considerations.

Conversely, end-product substitution imposed by certain federal government regulations has not been a frequent occurrence. The obvious reason for this is the free-enterprise system under which the U.S. economy operates, in which government regulations of any sort are discouraged unless these imposed in order to protect society's health and welfare.[2] Therefore, the substitution are implemented because of explicit considerations of societal welfare.[1]

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[1] See pages 1-7 through 1-9.

[2] See: S. Barbera, "Manipulation of Social Decision Functions", *Journal of Economic Theory*, August 1977, 91(3), pp. 419-430.

Thus, in the case where the manufacturer of certain end-product(s) results inthe generation and emission of hazardous wastes which represent a clear danger to the society, a government may choose to implement legislation and/or regulations which will result in substitution of this particular end-product by another end-product whose manufacture would not generate hazardous wastes.

However, such legislation and/or regulation is only one option the federal government may choose. The federal government has other legislative and/or regulatory options available which must, under the new regulations embodied in Executive Order 12291, examine all alternate approaches to regulation leading to could also result in reduction and/or elimination of hazardous waste generation and/or emission, including regulation of inputs i.e., raw materials associated with hazardous wastes, changes in technology i.e., production processes which reduce and/or eliminate hazardous wastes, abatement of hazardous wastes after they are generated, and levying taxes on end-products which generate hazardous wastes. There surely are other legislative and/or regulatory options which the federal government may use to reduce or eliminate hazardous waste generation.

The above options however, should underscore the fact that a number of different policy options are available. The

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1. On this see: A. Endres, "Monopoly--Power as a Means for Pollution Control", Journal of Industrial Economics, December 1978, 27(2), pp. 185-197.

theory as well as practice of the U.S. government is that of minimal intervention in free-enterprise economy.[1] Therefore, the legislative and/or regulatory option chosen by the federal government to reduce and/or eliminate hazardous wastes resulting from the manufacture of certain end-products should be that which has the minimum impact on the economic status-quo[2] and yet serves to reduce or eliminate hazardous waste generation.

In order to accomplish this, the federal government must, under the new regulations embodied in E.O. 12291 examine all alternate approaches to the regulation leading to end-product substitution and undertake a series of benefit/cost analyses for each alternative.[3]

Given this background and the requirements of Executive Order 12211, it is clear that regulations which would require end-product substitution are feasible only if such substitution has smaller economic impacts on the various parties impacted by such substitution than any other alternative.

In this context it may be necessary to explicitly address the issue of whether or not it is prudent to present this conceptual model for end-product feasibility analyses in concert with the requirements embodied in the Executive Order 12291.

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[1] See: R.K. Winter, "Economic Regulation vs. Competition", Yale Law Journal, April 1973, 82(5), pp. 890-912.

[2] See: E. Baltensperger, "Government Expenditure Policies in Equilibrium and Disequilibrium", Dyklos, 1977, 30(3), pp.421-42 and B.N. Angier and T.S. McCaleb, "Equilibrium Concepts in the Theory of Public Goods", American Economic Review, September 1978, 67(4), p. 764.

[3] See: Executive Order 12291, February 17, 1981 and Office of Management and Budget, Interim Regulatory Impact Analysis Guidance, June 13, 1981.

As already noted, the cardinal difference between the Executive Order 12291 and other past regulations is that this Executive Order explicitly mandates that alternative approaches to a specific federal government regulation be examined and benefits and costs of these compared. As already noted, there indeed exist a number of regulatory alternatives to end-product substitution for the purpose of hazardous waste reduction. However, these alternatives are not within the scope of this report and therefore need to be considered only when directly applicable to the conceptual model.

In light of this constraint, the conceptual model must be regarded as tentative from the point of view that conclusions resulting from this model with regard to the feasibility of end-product substitution may need to be modified if other regulatory alternatives are considered Note, however, the underlying fundamental assumption of this conceptual model: the lower the cost impact of an end-product substitution to all parties, the more feasible the substitution is. This is very much in accord with the fundamental assumptions embodied in Executive Order 12291.

APPROACH TO THE CONCEPTUAL MODEL

Our proposed approach to establishment of a model to measure the feasibility of end-product substitution is based on the premise that the smaller the economic costs to the parties impacted by such substitution the more promising is the feasibility of such substitution. We therefore propose to advance a series of measures which would indicate the relative magnitude of costs to each of the impacted parties.

The three principal parties which may be impacted by an end-product substitution are as follows:

1. users of the end-product;
2. manufacturers of the end-product;
3. suppliers of inputs (to the manufacturers of the end-product).

Three other parties which may also be impacted by end-product substitution, but most likely to a lesser extent, are:

1. importers of end-products;
2. importers of inputs to end-product manufacturers; and
3. exporters of end-products.

There may be of course, other parties which will be impacted by end-product substitution such as manufacturers of the substitute end-products. The impacts on all of these parties however, is expected to be positive i.e., these parties will gain economic benefits from end-product substitution. For example, the manufacturers of the substitute end-products may experience significant increases in demand for their products and therefore increased output, sales and profit.

While these changes may require certain federal government policies (i.e., windfall profit taxation), impacts which result from these changes have little, if any, bearing on the feasibility of end-product substitution. To put it in another way, the negative impacts, i.e., costs associated with an end-product substitution, determine the feasibility of such substitution.

There may also be other issues which affect the feasibility of end-product substitution and yet which may not be fully reflected in the costs. For example the substitute end-products may require inputs (i.e., raw materials) which, while in adequate supply prior to the initiation of the end-product substitution process, significantly increase in demand as the end-product substitution takes place. In such a case the cost impacts, while relatively small at the beginning of end-product substitution, may increase significantly.

Similarly, the substitute end-product manufacturing capacity may be limited at the initiation of the end-product substitution.[1] This will increase the costs of the substitute end-product at the beginning of the substitution process, followed by a decrease in costs as the substitution process progresses and manufacturing capacity is expanded.

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[1] For a general statement on this possibility see: R.C. Levin, "Technical Change and Optimal Scale: Some Evidence and Implications", Southern Economic Journal, October 1977, 44(2), pp. 208-21.

In both of these cases it is important to consider the end-product substitution impacts over time during which the supply and demand factors have had an opportunity to reach a new equilibrium.[1]

MEASURES OF MAGNITUDE OF IMPACTS

As already stated we propose to establish a methodology by which to measure the feasibility of end-product substitution by providing qualitative measures which may be converted into quantitative information on impacts resulting from end-product substitution.

Impacts on Users of End-Products

Among the parties which may be significantly impacted by end-product substitution are users of end-products.

In the case studies discussed in the previous chapters of this report,[2] end-product users were certainly one of the principal parties which may have experienced costs from end-product substitution. In the case of PCB transformers, some of the substitute transformers were somewhat more expensive. Concrete and steel piling costs, on a per unit basis, considerably more than treated wood piling. The same is true for pipes of PVC, clay, and iron substituted for A-C pipe.

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[1] This represents, of course, the conventional assumption under most economic analyses. For recent discussions on this see: P. Champrauer et al., "Stability Theorems with Economic Applications", Econometrica, March 1977, 45(2), pp273-94.

[2] See chapters 2 through 7.

Furthermore, if the users of an end-product are many (as in consumer end-products), the total cost of end-product substitution may be very large, even if the unit costs are small or even insignificant.[1]

In any event the cost impacts of end-product substitution on the users of end-products is an important consideration in determining the feasibility of such substitution.

There are four principal measures which may indicate in qualitative terms the magnitude of this impact. More likely than not the cost impact on the end-product users will be relatively small under one or more of the following conditions:

1. The end-product to be substituted has one or several competitive end-products[2] in the market, with significant shares of the market.

Substitution of PCB transformers is an example of this. Note also that the supply of several substitute end-products in the market will, most likely, reduce cost impacts to users.

2. The demand for the end-product to be substituted for is declining.

Benzene-based dyes for home use is a good example of such an end-product.[3] Replacement of asbestos with other superior heat retention materials, as in the wood burning stoves is another example, as is the use of wooden matches.[2]

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[1] Note that under the Executive Order 12291 it is the total costs, rather than unit, which determines procedures for regulation.

[2] We are assuming, of course, that these substitute end-products are superior with regard to reduced hazardous waste generation.

[3] Chemical Week, October 13, 1981.

3. The unit value of the end-product(s) to be substituted for and the substitute end-product is very low.

Bleached and unbleached toilet tissue and related paper products represent an example of this.[3]

4. The unit value of the substitute end-product is lower than the end-product to be substituted for.

The actual requirement here is that the life-cycle costs of the substitute end-products are lower than that of the end-product to be substituted for. However, this requirement is complex and complicated by such other factors as the perception by the user of true life-cycle costs, the average life span of the end-product, and the impact of a host of other regulations. With regard to this, a good example of these complexities can be seen in the life cycle costs of treated wood piling as compared to concrete pilings. The life-cycle costs of concrete pilings are allegedly lower than such costs of treated wood piling. Conversely, the unit price of treated wood piling is significantly below concrete pilings at the time of installation of such pilings. A significant portion of users of pilings,i.e., builders and developers of housing projects, however, choose to use the treated wood piling because purchasers of housing units do not perceive the concept of life-cycle costs of the piling and/or are willing to sacrifice lower life-cycle costs of concrete pilings in favor of lower unit price of treated wood pilings at the time housing units are purchased.[1]

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[2] See: Vulcan Stove Catalog, Boston, MA, 1981.

[3] Blair T. Bower, "Pulp and Paper Industry and Environment", (draft), Resources for the Future, Inc., Washington, D.C., 1979.

Conversely, the cost impacts of the end-product users will be relatively large and the end-product substitution may not be readily feasible under the following conditions:

1. The end-product to be substituted for has no competitive product in the market.

The absence of any other product in place of asbestos brake pads is an example of this.

2. Substitution of an end-product by another requires significant changes in operational practices associated with the original end-product.

An excellent example of this is the case of oxygen use in place of chlorine in paper mills for bleaching of paper pulp.[2] Also, significant reduction of pesticide use can be achieved by changes in farming practices, but such changes require significant modification in existing agricultural operations.[3] Finally, replacement of CFC-113 by certain other solvents would require the re-design of commercial dry-cleaning equipment.

3. The demand for the end-product to be substituted for is increasing.

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[1] Interview with Franc F. Macioge , Chief Architect, Western Development Corporation, Washington, D.C.

[2] Chesapeake Corporation, Use of High-Purity Molecular Oxygen in Pulping, West Point, VA, 1979.

[3] See: G.A. Carlson, "Long-Run Productivity of Insecticides", American Journal of Agricultural Economics, August 1977, 59(3), p. 543.

An excellent example of this is the more advanced "non-smudge" printing inks used in the printing of newspapers and periodicals.[1] THese allegedly contain substances suspected of carcinogenic affects in higher volumes as compared to older type printing inks. However, the demand for the more advanced inks is rapidly increasing.

At the risk of oversimplification, it can be generalized that it is less feasible and more costly to the user to substitute end-products which are relatively new to the market as compared to an end-product which has been in the market for some time. An additional reason for this lies in the fact that more likely than not, for a new end-product in the market, substitute end-products are less available because there has been insufficient time to develop competitive end-products.[2]

4. The unit value of the substitute end-product is high in relationship to the unit value of the end-product to be substituted for.

As already discussed, cadmium used in electroplating applications can be readily replaced by silver;[3] however, the cost differential of this substitution is, of course, excessively high.

There may be other measures which indicate the degree to which end-product substitution creates economic impacts on the users of such end-products, but the measures identified above comprise the major indicators.

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[1] See: Printers Ink, September 1, 1981.
[2] See: R.C. Levin, "Technical Change, Barriers to Entry and Market Structure", Economica, November 1978, 45(180) pp. 347-61.
[3] See Chapter IV.

Data Requirements and Sources

The measures identified and described above will provide significant assistance in determining whether or not a specific end-product substitution is feasible from the point of view of the end-product user, but only if the required data and information to do so are available.

It is difficult to provide an a priori description of data requirements and sources for a feasibility analysis of end-product substitution for the point of view of end-product user as presented above. Clearly the data requirements and the probable sources for such information will differ for each specific end-product, or at least for general types of end-products. Furthermore, the availability of the required data is inconsistent with required information readily available for some types of end-products and a paucity of such information for others.

For example, for almost all end-products which are chemical compounds, a significant proportion of required information is available from the SRI Chemical Handbook.[1]

For many other types of end-products there are no such systematic, periodic sources of information.

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[1] Stanford Research Institute, Chemical Handbook, Stanford, California, annual.

Similarly, the U.S. Bureau of Mines[1] annual Minerals Yearbook provides a large proportion of the required data for all mineral-related end-products.

For many other types of end-products there are no such systematic, periodic sources of information. Furthermore, for some end-products, significant information is available for a specific raw material or input used in the manufacture of the end-product rather than for the entire end-product. For example, there is detailed information available as to the magnitude of mercury used annually in electrical switches.[2] Information on the quantity and/or value of such switches manufactured annually is not available.[3] Note also that the information on the number and value of transformers manufactured (as discussed in Chapter 4 of this report) was obtained from special surveys. Conversely, the volume of PCB used in the production of PCB type transformers was reported by the Stanford Research Institute in their Chemical Handbook.[4]

There may be other end-products manufactured by a few firms for which information is not available because such information is regarded as proprietary by the firms manufacturing

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1. U.S. Bureau of the Mines, Minerals Yearbook, G.P.O., Washington, D.C., annual.
2. See: U.S. Bureau of the Mines, "Mercury", Minerals Yearbook, G.P.O., Washington, D.C., 1979.
3. This information is aggregated with other similar electrical products within ghe SIC 3613 "Switchear and Switchboard Apparatus" category.
4. See for example, SRI Chemical Handbook, Polychlorinated Biphenyls", Stanford,California, 1975.

their end-products and by the U.S. Bureau of the Census or other government organizations.[1]

Clearly, data sources and the availability of required data will vary significantly from one end-product to another. It is not possible to identify all of the data sources for all potential end-product substitutions. It is possible to indicate some of these sources and the type of information available by presenting such information for the six case studies presented in Chapters 2 through 7 of this report.

Feasibility measures of end-product substitution from the point of view of end-product users require at a minimum the following information:

- information on the existence of substitute end-products;
- market shares of the substitute end-product(s) as well as of the end-product to be substituted;
- demand trends of these end-products;
- comparative unit values of these end-products;
- information on changes in production and/or use processes required by the substitute end-products.

Existence of Substitute End-Products

The availability of the substitute end-product as a rule will be determined from appropriate engineering and technical studies, reports, and related documents.

A literature survey pertaining to the six case studies clearly indicates that the existing technical and engineering information for all six case studies is adequate to determine substitute end-products as well as to present a critical technical analyses of these end-products.

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[1] The rule with regard to the information on any product, by Federal Government agencies is that said product must be manufactured by at least three separate firms, none of which accounts for more than 50% of production before information on this product is realized.

However, sufficient technical information may not exist for all end-product substitutions. The presence of a very significant body of such information for the six case studies results from the fact that the manufacture and/or use of the original end-products generated at least some highly hazardous wastes, recognized as such by EPA, OSHA and other government agencies; and that a deliberate policy was undertaken by the federal government to determine possible substitutes for these end-products and to force implementation of such substitutes.

This in turn required research studies, during the course of which a considerable body of original data and information was collected. Note however, that there exists information for some end-products as to the availability of substitutes. SRI's Chemical Handbook[1] for example, describes for each major chemical compound its principal uses and conversely provides information as to the various chemical compounds which may be used in certain applications. Similar information is also presented in the U.S. Bureau of Mines Mineral Yearbook.[2]

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1. Stanford Research Institute, Chemical Handbook, Standford California updated annually.
2. U.S. Bureau of the Mines, Minerals Yearbook, G.P.O., Washington, D.C., annual.

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Demand Trends, Market Shares and Unit Values

The sources of information for these three variables are essentially the same.

The required data for these three and related variables were readily available from several sources for the six case studies. However, the same general caveat as presented above must be made here with regard to these data sources. That is, the regulatory focus on the end-product substitution presented in the six case studies has resulted in market-related information which may not be available for other end-products.

Table 43 presents information on the sources for these variable market related data. As the Table indicates, a significant proportion of the information required to undertake market study for the end-product substitution is available from published sources. In order to underline this point, a more detailed description of these sources is presented below. As noted in Table 44, SRI's Chemical Handbook[1] represents one of the principal data sources.

SRI's Chemical Handbook presents current (updated on an annual basis) information for all chemicals in terms of demand by sector of economy. The Handbook contains information some 6000 chemicals. Data are available on sales expressed in volume and value and unit prices trends. In the case of minerals and metals the Bureau of the Mines Minerals Yearbook[2] provides information on market demand trends. Additional data are provided by Bureau of Mines' Minerals Availability System (MAS).

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[1] Stanford Research Institute, Chemical Handbook, Stanford, California update annually.

[2] U.S. Bureau of the Mines, Minerals Yearbook, G.P.O., Washington, D.C., annual.

Information on the value of shipments and quality of shipments for some end-products is also available from the Annual Survey of Manufacturers[1] and Census of Manufacturers,[2] both published by the Bureau of Census. The principal difficulty in using this information results from the fact that many of the end-products correspond to five or six digit SIC codes, whereas the Bureau of the Census provide most of the required information on a four digit SIC level. For example, in the case of A-C pipe, information on this end-product is provided under SIC 3272 "Concrete Products, Except Block and Brick," with 90 different end-products included. (Table 44). Clearly, the Bureau of the Census information may be of very limited use.

There are other data sources which provide specific information on end-product groups. In the case of construction materials information on the market demand trends and unit prices is available from F.W. Dodge Reports.[3] Note that this source not only provides unit cost information for most construction products but also furnishes data on installation costs of these products.

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1. U.S. Bureau of the Census, Annual Survey of Manufacturers, G.P.O., Washington, D.C., annual.
2. Bureau of the Census, Census of Manufacturers, G.P.O., Washington, D.C., 1977 (the latest census year).
3. McGraw-Hill, F.W. Dodge Guide to Construction Materials, New York, NY, annual.

TABLE 43

SOURCES FOR MARKET DEMAND RELATED DATA

Item	Source of Data
1. Market Demand Trends	
PCB's	SRI, Chemical Handbook
Asbestos	Bureau of Mines, Minerals Yearbook
Cadmium	Bureau of Mines, Minerals Yearbook
Creosote	SRI, Chemical Handbook
Substitute Products	The same as above
2. Market Demand Share	
PCB's	There is no readily available information on this item, although information on market share can be developed from data presented in SRI Chemical Handbook.
Asbestos	The same as above.
Cadmium	The same as above, Minerals Yearbook, can be used to develop limited information on market share.
Creosote	The same as above. Note, however, that demand for creosote by specific wood product group i.e., piling, is not available. Rather the available information will provide data on creosote demand by all wood products treatment operations.
CFC's	The same as PCB's.

TABLE 43 (Continued)

Item	Source of Data
3. Historical Unit Price Trends	
PCB's	The same as for item 1. Note that for some end-products unit prices are provided only on "average" basis for all types, grades, etc. That is, unit prices may not be available for specific types or grades of end-products.
Asbestos	
Cadmium	
Creosote	
CFC's	

Market trends for most electrical goods are available from Edison Electric Institute's Annual Survey.[1]

The obvious shortcomings of both these sources is the absence of detail in the data. In both cases the market information provided is roughly on the basis of five digit SIC code. While such information is better than that supplied by the Bureau of the Census, it may not be specific enough. For example, Edison Electric Institute provides annual sales by demand sector for transformers, but does not differentiate by type.

Inter-industry demand information is, of course, available from various input-output tables. Here again, these data sources suffer from absence of detail. The most detailed input-output table is that of the Department of Commerce's Office of Business Economics[2] 362 sector table published last in 1972. The 362 sector roughly corresponds to three digit SIC level, and therefore is of limited value in an analysis of end-product substitution. Further, the technological coefficients of this table are dated. Nevertheless, this input-output table may be used to determine approximate inter-industry demand for certain end-products using the proportioned distribution method.[3]

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[1] National Association of Machinery Manufacturing, Survey of Equipment Trends, Washington, D.C., annual.

[2] Office of Business Economics, Input-Output Table of U.S. Economy (mimeographed), Washington, D.C., 1974.

[3] On this see: Ann Carter, Inter-industry Coefficients, Brandeis University, Boston, 1977 and R.C. Geary, "A Method of Estimating the Elements of an Inter-industry Matrix Knowing the Row and Column Totals", Economic Soc. Review, July 1973, 4(4), pp. 477-85.

TABLE 44

PRODUCT COVERAGE UNDER SIC 3272

Areaways, basement window: concrete
Art marble, concrete
Ashlar, cast stone
Bathtubs, concrete
Battery wells and boxes, concrete
Building materials, concrete: except block and brick
Building stone, artifical: concrete
Burial vaults, concrete and precast terrazzo
Cast stone, concrete
Catch basin covers, concrete
Ceiling squares, concrete
Chimney caps, concrete
Church furniture, concrete
Columns, concrete
Concrete, dry mixture
Concrete products, precast: except block and brick
Conduits, concrete
Copings, concrete
Covers, catch basin: concrete
Cribbing, concrete
Crossing slabs, concrete
Culvert pipe, concrete
Cylinder pipe, prestressed concrete
Cylinder pipe, pretensioned concrete
Door frame, concrete
Drain tile, concrete
Fireplaces, concrete
Floor filler tiles, concrete
Floor slabs, precast concrete
Floor tile, precast terrazzo
Fountain, concrete
Fountains, wash: precast terrazzo
Garbage boxes, concrete
Grave markers, concrete
Grave vaults, concrete
Grease traps, concrete
Housing components, prefabricated: concrete
Incineration, concrete
Irrigation pipe, concrete
Joists, concrete
Laundry trays, concrete
Lintels, concrete
Manhole covers and frames, concrete
Mantels, concrete
Mattresses for river revetment, concrete articulated
Meter boxes, concrete
Monuments, concrete
Panels and sections, prefabricated: concrete
Paving materials, prefabricated concrete except blocks
Pier footings, prefabricated concrete
Piling, prefabricated concrete
Pipe, concrete
Pipe, lined with concrete
Poles, concrete
Posts, concrete
Pressure pipe, reinforced concrete
Prestressed concrete products
Roofing tile and slabs, concrete
Septic tanks, concrete
Sewer pipe, concrete
Shower receptors, concrete
Siding, precast stone
Sills, concrete
Silo staves, cast stone
Silos, prefabricated concrete
Slabs, crossing: concrete
Spanish floor tile, concrete
Squares for walls and ceilings, concrete
Steps, prefabricated concrete
Stone, cast concrete
Stools, precast terrazzo
Storage tanks, concrete
Tanks, concrete
Thresholds, precast terrazzo
Tile, precast terrazzo or concrete
Tombstones, precast terrazzo or concrete
Wall base, precast terrazzo
Wall squares, concrete
Wash foundations, precast terrazzo
Well curbing, concrete
Window sills, cast stone

Source: Office of Management and Budget, Standard Industrial Classification Manual, GPO Washington, D.C., 1972.

Finally, for some end-products (especially chemicals, electronic goods, special industry machinery, and ceramic products) much detailed information is available form reports published by the U.S. International Trade Commission.[1]

Note, however, that this source does not provide information on any systematic basis. Rather, the information is collected in conjunction with various trade related issues before end-product substitution is readily available while some is difficult to obtain from conventional data sources.

Impacts on Manufacturers of End-Products

Manufacturers of end-products to be substituted for represent an important impacted party by such substitution. The impacts on the end-product manufacturers discussed in the case studies presented in the previous chapters of this report were not very significant. However, this was due to a number of factors which may have been unique to the case studies selected and should not be assumed to be true for all manufacturers. Among the unique factors which alleviated the cost impacts on end-product manufacturers discussed in the case studies were the following:

- the end-product to be substituted represented a very small fraction of the output of the manufacturers (i.e., PCB manufactured by Monsanto Chemical Company) and;
- the same manufacturer(s) produced the end-product to be substituted as well as the substitute end-product (i.e. manufacturers of PCB

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[1] See for example: U.S. ITC, Chemical, Report 862, Washington, D.C., 1978.

transformers also produce non-PCB transformers; manufacturers of A-C pipe also are leading producers of PVC pipe).

Clearly, this may not uniformly be the case, and end-product substitution may indeed have significant cost impacts on manufacturers.

In terms of a fully developed and executed economic analysis, the cost to a firm associated with the substitution of an end-product for another, and to a firm which manufactures this end-product to be substituted, can be estimated using conventional real resource cost estimation methodology. Using this methodology, real resource costs are the (opportunity) costs incurred by firms complying with regulated end-product substitution, net of any transfer payments. In practical terms, real resource costs can be approximated by summing the actual investment costs and discounted annual costs (operating and maintenance and other annual regulatory costs).

The conceptual framework for such cost analysis that has been suggested (based on a static, partial equilibrium approach) can be illustrated graphically.[1] Figure 14 illustrates the general impact of an end-product substitution that increases production costs in a single market. The supply curve shifts from S to S' by the change in price required to recover all compliance costs. In the long run this includes a required return on investment at each level of output--the curve shifts upward by the additional "revenue requirement" for each level of output. This shift represents the regulatory costs to the firm. Some end-products to be substituted will have supply curves that appear relatively "flat" or inelastic, because they are bought on an international market or due to the nature of production processes, input supply, or least-cost size considerations of the industry. Real resource cost estimations should allow for such situations.

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[1] See: Environmental Protection Agency, Required Analyses Under E.O. 12291 (draft), October 1981.

Given estimates of the end-product substitution expenditures required per unit of output for each point on the supply curve, the shift in supply can be calculated as follows:

$$\text{Shift in supply curve (or costs to the firm)} = C_1 + \frac{C_2}{(1 - t)}$$

where C_1 = tax deductible end-product substitution costs,

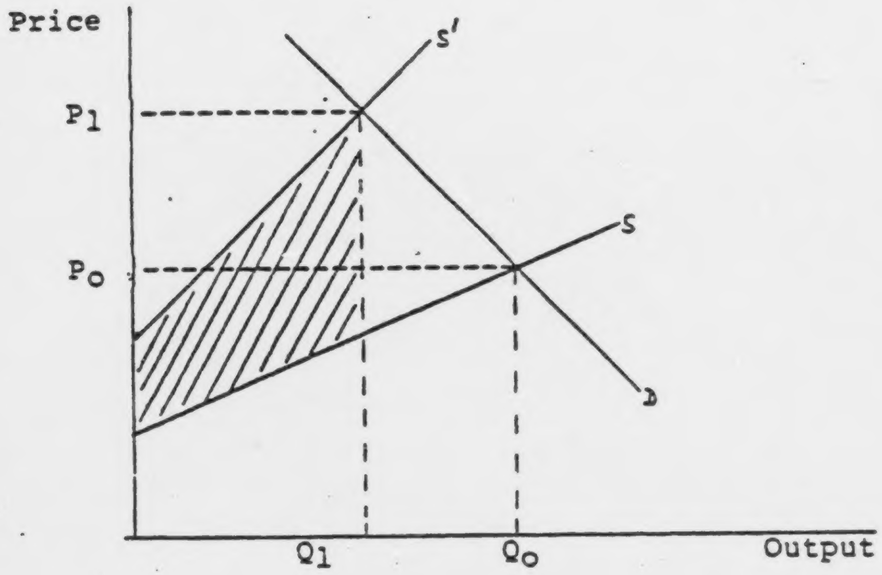
C_2 = non-tax deductible end-product substitution costs, and

t = the marginal tax rate.

Several of the end-product substitution costs components such as operating and maintenance costs, interest payments, and depreciation are tax deductible. Others, such as a required return on equity-financed capital investments, are not tax deductible. Therefore, the supply curve shift must ultimately include the recovery of actual expenditures, a return on investment, and an amount to cover taxes paid on that return and other non-deductible items.

Figure 14

Revenue Requirements Associated with Compliance Expenditures - Competitive Market



Once a supply curve shift has been projected, and assuming availability of demand elasticity information, new end-product substitution induced price and output levels can be estimated. Figure 15 indicates that the new price and output levels are at P_1 and Q_1 respectively. The shaded area represents costs to the firm, based on the end-product substitution expenditures. Real resource costs are calculated by netting out transfer payments directly resulting from these additional costs. Figure 15 illustrates the result after transfer payments are netted out. The shaded area represents transfer payments that are subtracted from costs to the firm. Transfer payments include some types of taxes and certain insurance payments (for already-existing liabilities).

Netting out tax costs is essentially a question of transition effects vs. long-run effects: in the long-run, the firm will recover tax costs. The short-run or transition effects may result in a firm's profitability declining below the market level because it does not immediately recover the tax costs. The area remaining from original costs (area a) represents real resource costs.

The cardinal problem with the methodology presented above is that such analyses would require considerable resources and data for each end-product substitution. Thus, while the approach is correct in terms of economic analysis its implementation would require time, resources and data far beyond the capacity of a program which proposes to evaluate a number of potential end-product substitutions in order to reduce hazardous waste generation. Therefore, another much simpler, but cruder methodology is proposed and presented below. It must be emphasized however, that this much simpler method of estimating the costs i.e., feasibility of end-product substitution, is based on very approximate measures of certain selected variables.

This much simpler feasibility analysis simply assumes that more likely than not, the cost impact on the end-product manufacturers will be relatively small under one or more of the following conditions:

1. The end-product substituted represents a small fraction of the total output by the end-product manufacturer.

As already noted, a good example of this is the manufacture of PCB, undertaken by only one firm in the U.S. (Monsonto) with a total value of PCB output representing a fraction of one percent of the total sales of this firm.

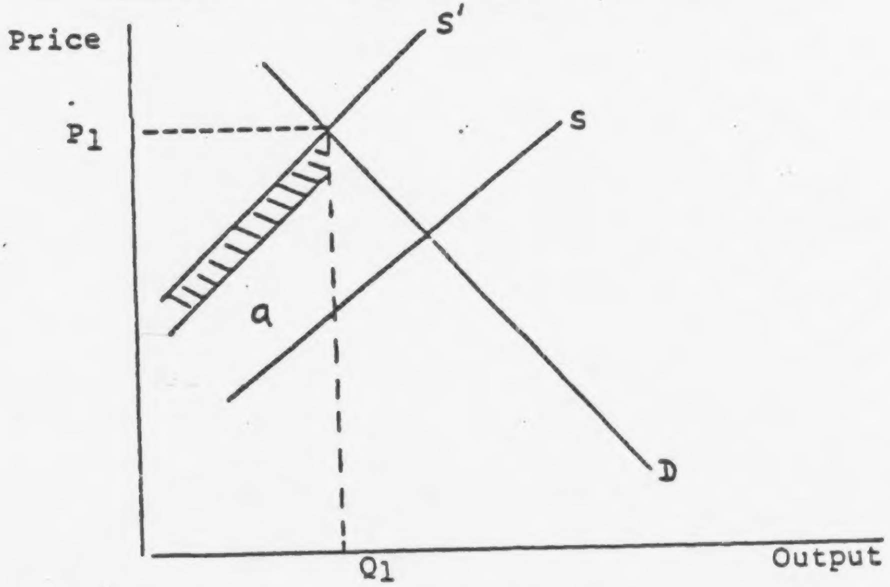
A variant of this condition exists if the end-product to be substituted for is declining in demand, output, and therefore sales. A good example of such products are the older type of polyester resins which are being rapidly replaced by various better performing plactic resins.

2. The capital invested in end-product manufacture can be readily, or with the marginal additional outlay of monies, be put to use in the manufacture of other products.

As noted elsewhere in this report, most of the equipment used in the manufacture of organic chemical end-products have this characteristic. Note, however, that it is quite possible that this equipment will be of use in the production of end-products which also generate hazardous wastes.

Figure 15 [1]

Real Resource Costs Net of Transfers



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1. Real resource costs may be either less (as is the case here) or more than revenue requirements, depending on the nature of the transfers.

For example, equipment used in the manufacture of CFC-113 can be readily converted to produce a number of other products (some of which are readily substituted for CFC-113). Manufacture of all of these products however, generate some hazardous wastes and therefore, from the point of view of hazardous waste reduction, little may be accomplished, although from the point of view of reduced impact costs of the manufacturer, such substitution is very feasible.

Another related consideration here is the vintage of technology employed in the manufacturing operations and the state of equipment depreciation. It is reasonable to expect that the technology embodied in the production processes used to manufacture end-products to be substituted for has been surpassed by much more advanced technologies. It may also be that the equipment used has been depreciated to such a significant extent that the economic impact of closing such a facility is not significant.[1]

3. End-products to be substituted for and the substitute end-product(s) are manufactured by the same firm.

Many of the organic chemical end-products are produced by the same firms because of the characteristics of the organic chemical manufacturing processes (note that in the case of PCBs, they were manufactured by only one chemical firm). As indicated in the case studies,[1] the same electroplating firms usually can and do produce products electroplated with cadmium, zinc and other coatings, and therefore substitution of one metal coating for another would result in only marginal, if any, cost impact on the manufacturer.

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[1] On this see: R.W. Broedwag and N. Bruce, "Depreciation and Interest Reductions and the Effect of the Corporation Income Tax on Investment", Journal of Public Economics, February 1979, 11(1), pp. 93-105 and H. Bierman, Jr. and R.E. Dukes, "Limitations of Replacement Cost", Quarterly Review of Economics and Business, Spring 1979, 19(1), pp. 131-40.

The following conditions most likely would result in significant cost impacts on the manufacturers of end-products to be substituted:

1. The end-product to be substituted represents a significant fraction of firm's output.

For example, many of the medium and small size manufacturers of A-C pipe specialize in A-C pipe production. Wood treatment plants undertake only one manufacturing operation--that of treating lumber in various forms for resistance against various pests. In this case it may be more severe if the end-product to be substituted for and the substitute end-product are manufactured by different firms. Under such conditions, the resulting cost impact of substitution on the manufacturer of the end-product to be substituted for may be very significant.

2. The equipment used in the production of the end-product to be substituted for has no or limited use in production of other end-products.

Again, a good example of this is the equipment used in the treatment of lumber products. However, the magnitude of this impact will depend on the state of depreciation of the equipment as described above.

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[1] See Chapter II through VII.

There are several other factors which may impact and/or modify the magnitude of the cost impact on the manufacturer of the end-product to be substituted for.

1. The magnitude of any impact on the manufacturer of end-products to be substituted for will be more severe in times of economic depression;
2. the magnitude of any impact on the manufacturer of end-products to be substituted for will be more severe if there exists over-capacity of production facilities;
3. cost impact on the manufacturer of end-products to be substituted will be more severe if the manufacturer has not been able to recover the R&D product development and marketing expenses associated with the end-product to be substituted.

The latter factor suggests, again, that substitution of end-products may be more feasible in those cases where the end-product has been on the market for some time. Conversely, the feasibility of end-product substitution for products have been introduced into the market more recently may be difficult to achieve.

In conclusion, the feasibility of end-product substitution from the point of view of the manufacturer of the end-product to be substituted for depends to some degree on the structure of the sector of the economy to which the manufacturer belongs. If such a sector is comprised of large multi-product firms, the cost impact of end-product substitution may be relatively modest.

If however, the manufacturer of the end-products to be substituted for has significant product concentration rations, the cost impact of end-product substitution may be very large.

Data Requirements and Sources

In general terms the sources for data requirements to measure the feasibility of end-product substitution with regard to the manufacturers of the end-products are fewer as compared to the sources for data to measure the impact of end-product substitution of the users of end-products. Futhermore, the data and the required information are much more difficult to obtain.

This essentially results from the fact that most of the information required to measure the impacts of end-product substitution of the manufacturers pertains to the firm(s) and has been traditionally regarded as proprietary information for the firms i.e., manufacturers.

This is especially the case where the end-products are manufactured by only a few firms. Nevertheless, there are some data sources which will provide at least some of the information required.

At the minimum the following information is required:

- for firms manufacturing end-products to be substituted the fraction said end-product comprises of the total output of the firm;
- information on whether or not the same firm(s) manufacture end-product(s) to be substituted and substitute end-products;
- information on whether or not capital [illegible] used in the manufacture of the end-products to be substituted can be put to use in the manufacture of other products and related information or capacity

Table 45 indicates available information sources for these variables. A more detailed discussion of the sources of data listed in Table 45 is in order.

Fraction of Output Represented by End-Product

As already indicated there are no government statistics on the fraction of a firm's output represented by end-product to be substituted. Some of this information may be obtained from individual firms' SEC 10-1C Reports but considerable manipulation of figures may be required. Further difficulty may arise from the fact that a typical SEC 10-1C Report reports output by broad classes of end-products, without separately identifying each.

Additional information may be obtained for certain industry sectors from various handbooks. The already identified SRI's Chemical Handbook is one such source. Here again, however, the required data can be obtained only after manipulation of data-specific addition of values of all chemical products manufactured by a firm.

In summary, information on the fraction of output represented by the end-product to be substituted is very difficult to obtain, and only approximate information on this variable will be available.

Identification of Firms Manufacturing End-Products

There are no official government sources which identify manufacturers of specific end-products. Such information is available from various manufacturing directories published and available for various sectors of the economy.

Information Related to Various Capital Values

As already noted the determination of the feasibility of end-product substitution i.e., the cost to the manufacturer, requires information pertaining to the following variables

TABLE 45

SOURCES FOR MARKET SUPPLY RELATED DATA

Item	Source of Data
1. Fraction of Output represented by end-product to be substituted.	
PCB's	There are no official data on this variable. Some information may be developed using data from SEC 10-K Reports.
Asbestos	
Cadmium	
Creosote	
CFC's	
2. Information on which firms manufacture end-products.	
PCB's	This information is available SRI's Chemical Handbook for these chemicals/minerals. In general, this source will provide such information for all chemical end-products. Various manufacturing directories may provide related information for non-chemical end-products.
Asbestos	
Cadmium	
Creosote	
CFC's	
3. Capital Related Information.	
3a. Domestic Capacity	
PCB's	There are no official government estimates or industry capacity for any industry published on regular basis. National Bureau of Economic Research publishes annual data on this, although as described below, this information is provided on the basis of broad industry categories.
Asbestos	
Cadmium	
Creosote	
CFC's	
Substitute end-products	

TABLE 45 (Continued)

Item		Source of Data
3b.	Vintage of Technology	
	PCB's	
	Asbestos	
	Cadmium	There are no official or other systematic data on the vintage of technology employed for any sector of the economy.
	Creosote	
	CFC's	
	Substitute end-products	
3c.	Sunk Capital Costs	
	PCB's	
	Asbestos	Information on fixed gross assests value for all sectors of economy is available from the Bureau of Census. Unfortunately this information is available only on four digit SIC level.
	Cadmium	
	Creosote	
	CFC's	
	Substitute end-products	
3d.	New Capital Expenditures	
	PCB's	As in item 5, the Bureau of Census provides data on annual new capital expenditures for all four digit SIC sectors. Much more detailed data on a level of a firm for new capital expenditures are available from Securities and Exchange Commission 10-K Reports.
	Asbestos	
	Cadmium	
	Creosote	
	CFC's	
	Substitute end-products	

related to capital used in the manufacture of the end-products:

- capacity
- vintage of technology
- sunk capital costs and
- new capital expenditures

There is no regular information published by the government on capacity utilization of any industry sector, although such information may be available from time to time on a specific industry.[1] The National Bureau of Economics Research,[2] on the other hand, publishes annualindustry capacity estimates, albeit only on a three and four digit SIC basis. Clearly, the required industry capacity information is not readily available from published sources and needs to be estimated.

The vintage and type of technology employed in any one industry is not readily available from any source. Some information on this is available from a series of reports published by the Environmental Protection Agency which were used as a basis for obtaining the "best practicable technology" and "best available technology" standards for water pollution abatement.[3] A total of seventy-two sectors of industry are covered in these reports, roughly responding to three digit SIC industry categories.

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[1] See for example, Department of Labor, BLS "Capacity Measures in Organic Chemicals Industry" (mimeographed), July 1979.

[2] National Bureau of Economic Research, "Domestic Industry Capacity", Studies on Income and Wealth, New York, NY, 1979.

[3] See for example: Development Document for Effluent Limitations Guidelines for Textile, Friction Materials and Sealing Devices Segment of the Asbestos Manufacturing, G.P.O., Washington, D.C., December 1974.

Some information on the vintage of technology employed can be obtained from the "gross fixed assets" data published by the Bureau of the Census, and available on a four digit SIC industry basis annually, since 1947.

Annual additions to capital stock on four digit SIC basis is also available from the Bureau of the Census. Note, however that on a level of a firm new capital expenditures are available from the Securities and Exchange Commissions 10-K Reports.

Note that almost all of the capital related variables relate to financial information pertaining to a firm and/or industry sector. Therefore, a discussion of the sources of financial data is in order.

There are few federal government agencies which provide required financial data. Conversely, two private firms provide some of the data required. These two firms are Robert Morris Associates[1] and Dunn and Bradstreet Inc.[2] Both of these firms provide almost identical financial information for each and every four digit SIC industry but not for individual firms. The type of information available from these two sources is shown in Table 46.

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1. Robert Morris Associates, Statement Studies, New York, NY, (annual).
2. Dunn and Bradstreet, Income Statements, New York, NY, (annual).

TABLE 46

FINANCIAL INFORMATION AVAILABLE FROM DUNN AND BRADSTREET AND ROBERT MORRIS ASSOCIATES FOR FOUR SIC DIGIT SECTORS OF ECONOMY

Assets

Cash & Equivalents
Accts. & Notes Rec.-Trade (net)
Inventory
All Other Current
Total Current
Fixed Assets (net)
Intangibles (net)
All Other Non-Current
Total

Liabilities

Notes Payable-Short Term
Cur. Mat-L/T/D
Accts. & Notes Payable Trade
Accrued Expenses
All Other Current
Total Current
Long Term Debt
All Other Non-Current
Net Worth
Total Liabilities & Net Worth

Income Data

Net Sales
Cost of Sales
Gross Profit
Operating Expenses
Operating Profit
All Other Expenses (net)
Profit Before Taxes

Ratios

Current
Sales/Receivables
Cost of Sales/Inventory
Sales/Working Capital
Fixed Worth Assets (net)
Debt Net Worth
% Profit Before Taxes/Tangible Net Worth
% Profit Before Taxes/Total Assets
Sales/Total Assets
Net Sales (in thousands)
Total Assets (in thousands)

The other principal source for financial information for individual firms is the Securities and Exchange Commission's 10-K Reports required to be filled out annually by all publicly-held corporations. Tables 47 through 49 present the minimum financial data reports required by SEC from each corporation.

As the information presented in these tables indicates, the SEC 10-K Reports contain much of the financial information required. There are, however, two types of difficulties in using this source of financial information. The first of these pertains to the fact that this information is available only on the basis of individual firms. Thus, in order to establish an industry-wide financial data base the various firms' SEC 10-K Reports must be aggregated. For end-products which are produced by many firms this aggregation may be a time consuming and expensive undertaking, especially since the financial data reports are not uniform. The firm of Disclosure, Inc. has computerized the 10-K data base, however, considerably lightening the load.

The second difficulty arises from the fact that most large and even medium sized firms manufacture a number of end-products of which only one or a few are subject to end-product substitution feasibility analyses, while the financial data pertain to the entire product line manufactured by a firm.

While Securities and Exchange Commissions regulations pertaining to "line of business" segment information do require a

TABLE 47

STATEMENT OF INCOME - SEC 10K REPORTS

NET SALES

OPERATING EXPENSES
   Cost of goods sold
   Selling, general and administrative expenses
   Total

OPERATING INCOME

OTHER INCOME AND EXPENSE
   Interest expense
   Investment and other income - net
   Total

INCOME BEFORE INCOME TAXES

PROVISION FOR INCOME TAXES

NET INCOME

NET INCOME PER AVERAGE SHARE OUTSTANDING

TABLE 48

BALANCE SHEET - SEC 10-K REPORTS

ASSETS

CURRENT ASSETS
- Cash and interest-bearing bank deposits
- Marketable securities, at cost which approximates market
- Accounts receivable, less allowance of $55,100 in 1980, $47,400 in 1979 and $40,300 in 1978
- Inventories
  - Finished goods
  - Work in process
  - Raw materials and supplies
    - Total inventories
- Other current assets
- Total current assets

INVESTMENTS
- Equity in unconsolidated affiliates
- Other investments - at cost
  - Term investments held for retirement of 8.20% notes
  - Other
- Total investments

PROPERTY, PLAND AND EQUIPMENT - at cost
- Land
- Buildings and leasehold improvements
- Machinery and equipment
- Construction in progress
- Total property, plant and equipment
- Less accumulated depreciation
- Property, plant and equipment - net

OTHER ASSETS

TOTAL

LIABILITIES AND STOCHOLDERS' EQUITY

CURRENT LIABILITIES
- Accounts payable
- Payrolls
- Income taxes
- Other taxes and sundry liabilities
- Short-term debt outside the U.S.
- Long-term debt - current portion
- Total current liabilities

TABLE 48 (Continued)

DEFERRED INCOME TAXES

OTHER LIABILITIES

LONG-TERM DEBT
  Notes
  Sinking fund debentures
  Other
  Total Long-Term Debt

STOCKHOLDERS' EQUITY
  Common stock, without par value
  Authorized
  Issued
  Reinvested earnings
  Treasury stock
  Stockholders' equity - net

TOTAL

TABLE 49

STATEMENT OF CHANGES IN FINANCIAL POSITION - SEC 10-K REPORTS

SOURCE OF FUNDS
- Net income
- Depreciation and amortization
- Deferred income taxes
- Other - net
  - Total from operations
- Increase in long-term debt
- Disposal of property, plant and equipment
- Common stock issued, including treasury stock
- Total sources

USE OF FUNDS
- Capital expenditures
  - Plant and equipment
  - Equipment for lease and other property
- Dividends paid
- Decrease in long-term debt
- Purchase of treasury stock
- Increase in other investments
- Other - net
- Total Uses

INCREASE IN WORKING CAPITAL

ANALYSIS OF INCREASE IN WORKING CAPITAL
- Cash, interest-bearing bank deposits and marketable securities
- Accounts receivable
- Inventories
- Other current assets
- Income taxes payable
- Other current liabilities
- Debt due withone one year

INCREASE IN WORKING CAPITAL

breakdown of financial information by segments of business, these regulations are new (established in 1978) and therefore subject to further development.

In summary, data sources for financial information are readily available providing the end-product for which substitution feasibility study is undertaken represents four digit SIC code. If the end-product(s) correspond to a more detailed SIC code, SEC 10-K Reports must be used as sources of financial information. This in turn may create significant problems if the firm(s) responsible for the manufacture of the original and/or substitute end-products are multi-product firm(s).

In summary, the available data sources to estimate the impacts of end-products are relatively few. Furthermore the required data is relatively difficult to obtain and in most cases requires certain manipulation.

The fundamental reason for all of these difficulties lies in the proprietary nature of the information that is required, i.e., data on the business of a firm pertaining to operations, profits, losses, etc., of a firm.

The methodology for establishing the impacts of end-product substitution as presented above has been selected in order to provide the minimum data requirements, (and certainly requires far less data than the economic real resource cost approach presented in the introduction to this chapter.

Impacts on Suppliers of Inputs

Suppliers of inputs and/or raw materials to the manufacturers of end-products to be substituted for may be the manufacturers of such end-products, another manufacturing firm, or a dealer (wholesaler, jobber, etc.)

In all cases the most critical impact of end-product input suppliers is not the type of organization and/or structure that the input suppliers represent, but rather the supply and demand characteristics of the inputs per se.

The impact of end-product substitution on the suppliers of inputs to the manufacturers of the end-products to be substituted will, most likely, be relatively small and the feasibility of such substitution greater if the inputs are required for uses other than in the production of end-products to be substituted.

A good example of this can be found in organic chemical manufacturers. The basic raw materials for organic chemicals are the same and can be used in the manufacture of large numbers of alternative organic chemicals. Therefore, the suppliers of basic feedstock used to manufacture organic chemicals would experience marginal, if any, impacts resulting from the substitution of one or several end-products which use feedstock as the basic raw material.

Conversely, the magnitude of cost impacts on the suppliers of inputs to the manufacturers of end-products to be substituted will be significant if the inputs have very narrow uses and are principally destined to be used by those manufacturers who produce end-products to be substituted.

Substitution of A-C pipe with other types of pipe (as well as other asbestos consuming products), for example, would have significant cost impact on the producers of asbestos.

One can readily conclude that suppliers of basic inputs (i.e., raw materials) to the manufacturers of end-products that are to substituted are likely to experience less cost impact in the event of an end-product substitution than will those suppliers which provide more specific (i.e., value added) inputs.

The reason for this is quite clear: more basic inputs can be used in more applications. As the basic inputs are modified, the range of applications where such inputs can be used is diminished.

The above conclusion, however, does not apply, in the case of end-product substitution undertaken to reduce hazardous waste generation, to those basic inputs and/or raw materials which embody the very properties which lead to hazardous waste generation. For example, in the case of A-C pipe substitution, suppliers of asbestos used in the manufacture of A-C pipe will be adversely affected by the substitution of A-C pipe. Conversely, suppliers of cement to the A-C pipe manufacturers will be affected only to a marginal degree by A-C pipe substitution.

Data Requirements and Sources

The data required to estimate the cost impacts on the suppliers of inputs to the manufacturers of end-products in the event of end-product substitution are as follows:

- o the type and magnitude of the inputs used; and
- o potential other uses of the inputs used.

Three distinct sources may assist in identification of the type and magnitude of the inputs used for any one end-product. The first of these is the conventional inter-industry of the U.S. economy.[1] Each of the coefficients, a_{ij}, in inter-industry tables represent the amount of input i required to produce a unit output of industry project j. A fundamental assumption of input-output analysis is that input requirements are proportional to outputs. Thus, the total production of output of industry i, X_k, is equal to final demand for output i, Y_k, plus all of the inputs required to produce the outputs of the other industries, so

$$X_1 = Y_1 + a_{11}X_1 + a_{12}X_2 \; . \; . \; . + a_{1j}X_j + \ldots a_{1n}X_n$$

. . . .

$$X_i = Y_i + a_{i1}X_1 + a_{i2}X_2 \; . \; . \; . + a_{ij}X_j + \ldots a_{in}X_n$$

. . . .

$$X_n = Y_n + A_{n1}X_1 + a_{n2}X_2 \; . \; . \; . + a_{nj}X_j + \ldots a_{nn}X_n$$

Expressing this in matrix form,

$$X = y + Ax$$

Or, solving for x,

$$x = (I-A)^{-1}y$$

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[1] U.S. Department of Commerce, Input-Output Structures of U.S. Economy. G.P.O., Washington, D.C., 1974.

where x is a vector of total demand, y is the vector of final demand, A is the matrix of input-output coefficients, I is the identity matrix, and $(I-A)^{-1}$ is the inverse matrix. Thus, use of the input-output matrix allows derivation of total demand from final demand in a direct way. As long as the matrix A does not change, any change in final demand can be converted into changes in total demand by multiplication.

Thus, for any end-product to be substituted, simple multiplication of the total annual output of this end-product by appropriate cells in the input-output table will yield all of the required inputs (in terms of dollars). This input-output data manipulation will also establish all of the inputs by sectors of economy which supply inputs to an end-product manufacturer.

The fundamental problems with using the input-output approach is that the input-output sectors, as a rule, are too aggregated to apply to any one end-product. That is, the sectors to usually correspond to more than one end-product. This fact will often prohibit the use of the input-output approach to establish inputs for an end-product substitution. Note, for example, that because of this, input-output tables could not be used in any one of the case studies presented in this report.

The other source which identifies the inputs by type and magnitude is the U.S. Bureau of the Census' Census of Manufacturers.[1] This source identifies for each major product all major inputs i.e., materials consumed in the manufacture of this product during the year of the census. All major inputs are identified in terms of physical units as well as value.

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[1] See: U.S. Bureau of the Census, Census of Manufacturers -112-1977 P.O., Washington, D.C., 1980.

There are two problems with using this source to estimate inputs in the end-product manufacture. The first of these pertains to the fact that some minor inputs are either not included or are aggregated in larger categories. For example, certain chemicals may be aggregated into the "industrial chemicals" category.

The second problem stems from the fact that the inputs identified and reported are the "value added" direct inputs used in the production of the end-product.

Therefore, inter-industry impacts resulting from changes in inputs used for the manufacture of end-products cannot be really identified from this source.

The third source for these studies are various ad-hoc reports, documents and other technical literature. These include, among others:

- various reports prepared under the National Bureau of Standards technology transfer program;
- reports prepared for the National Science Foundation under Technology Assessment and Risk Analyses programs;
- reports prepared for the Department of Commerce under Strategic Materials programs;
- various reports prepared for the Environmental Protection Agency;[1]

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[1] See for example: L.A. Abron-Robinson and E.J. Martin, Treatment Alternatives for Hazardous Waste Management in Nine Industry Groups, by Reer Consultants, Inc. for the Environmental Protection Agency, 1980; A.K. Schwartz, Jr. and R.G. Thompson, An Integrated Powers Process Model of

- reports on occupational health prepared for OSHA.

It is not possible to specifically identify which of these sources will provide information which will be useful in determining the type and magnitude of inputs used for an end-product, and clearly, there may be products for which original research may have been undertaken.

There is no single source of information of potential other uses of the inputs used in the manufacture of an end-product. The input-output table may provide some information on this, although because of aggregation of products in the input-output table this source may have limited usefulness. The SRI Chemical Handbook does provide explicit information on chemical uses, but only for chemical compounds.

Similar information is available for minerals and metals from the U.S. Bureau of Mines Minerals Yearbook. (See Tables 50 and 51. For other input uses, again, one may have to undertake original research.

Impacts on Other Parties

The other parties which may be impacted by end-product substitution are importers of end-products to be substituted, importers of inputs to end-products to be substituted, and exporters of end-products to be substituted.

The impacts resulting from end-product substitution on those parties will, most likely, not be large. In part this is

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1. (cont from pg 37) Water Use and Waste Water Treatment in Olefins Production, NSF (RANN) G1-34459-1 Technical Report, University of Houston, Texas, January 1974.

TABLE 50

ESTIMATED U.S. CADMIUM CONSUMPTION BY SECTOR, 1979

Use Category	Millions of Pounds
Electroplating	5.2
Pigments	1.3
Stabilizers	1.1
Batteries	2.3
Other	0.3
	10.2

SOURCE: U.S. Bureau of Mines, *Minerals Yearbook 1979* (draft), Washington, D.C. 1980

TABLE 5

ESTIMATED ASBESTOS FIBER CONSUMPTION BY SECTOR, 1979

Use Category	Thousands of Tons
Paper	260,000
A-C Pipe	150,000
Flooring	113,000
A-C Sheet	65,000
Friction Materials	54,200
Coatings and Paints	48,000
Textiles	26,200
Plastics	21,500
Drilling Fluids	20,000
Joint Cements	10,000
Gaskets and Packing	5,200
TOTAL	773,200

SOURCE: U.S. Bureau of Mines, Minerals Yearbook, 1979 (draft) Washington, D.C. 1980.

the result of the fact that all of these parties essentially perform functions such as storage, shipping, distribution and related activities for either end-product and/or inputs to end-products. The additional value added resulting from these functions (as well as profit) is, as a rule, relatively modest and therefore, renders relatively small cost impacts.

To be specific the average profit margin and therefore, the potential costs to the U.S. importers of various goods and commodities averages from 3 percent to 9 percent of total retail value of the goods and commodities imported.[1]

The average profit to the U.S. exporters averages 4 percent to 10 percent of the value of goods exported.[2]

It is not likely therefore, that the cost impact resulting from end-product substitution would affect the feasibility of such substitution.

There are three other impacts which may affect the feasibility of the end-product substitution that are identified in Executive Order 12291 and which therefore merit a brief discussion.

The first of these pertains to impact on geographic regions. While the full operational meaning of Executive Order 12291 is not as yet clear, nor has it been tested in an application, it seems to indicate that in the case where a

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1. International Trade Commission, Trade Statistics, USITC Publication 677, Washington, D.C., 1980.
2. See: G. Fishelson and A.L. Hillman, "Domestic Monopoly and Redundant Tariffs, Journal of International Economics, February 1979, 9(11), pp. 47-55.

regulatory action results in significant impact on a region, other regulatory alternatives must be considered. Thus, if a significant proportion of end-products to be substituted are, for example, manufactured in one or a few locations, substitution of such end-products may not be feasible under Executive Order 12291.

The second impact pertains to the fact that any and all federal regulations must ensure that economic competition is maintained. In the event an end-product substitution results in less competition, here again, the feasibility of such substitution may be challenged.

CHAPTER IX

REVIEW OF PAST FEDERAL POLICIES AFFECTING END-PRODUCT SUBSTITUTIONS

The objective of this chapter is to present a review of past federal policies aimed at or affecting end-product substitutions. This review includes a description of the policies which have resulted in end-product substitution, an analysis of the costs and benefits of such substitution, and a critical analysis of such actions and ranking of such policies.

This chapter consists essentially of two parts. The first part contains a comprehensive analysis of various government regulations which affect an end-product substitution. The second part presents a specific analysis of the effects of government end-product regulations in the one area where the federal government has explicitly required end-product substitution -- that of certain pesticide cancellations.

Government Policies and End-Product Substitution

The process of end-product substitution is undertaken for a variety of reasons, as already discussed. However, in many cases it is affected by various federal government regulations and policies. Some of these, such as outright cancellation of certain pesticides, are explicitly directed at end-product substitution. Many other government policies, however, are not so directed and yet have considerable impact on substitution.

The policies and regulations which impact on the end-product substitution include, among others, federally-funded research and development activities, federal procurement policies, trade policies, patent regulations, tax policies, regulations related to environmental quality, and occupational health and welfare, as well as others. The following sections will analyze and discuss these government policies and regulations,

Federal Research and Development Funding

Introduction of any new end-product and/or substitute end-product requires significant outlays for research and development. In 1980, the total expenditures for research and development by all sources (i.e., federal government, industry, universities and others) was almost $60.4 billion, certainly a significant expenditure (Table 52). As the data in Table 52 indicate, the federal government's funding of these expenditures represented 48.7 percent as compared to industry's 47.6 percent. Thus, almost one-half of the total research and development expenditures undertaken in the United States in 1980 were funded by the federal government.

The year 1980 is not an exceptional year; as the data in Table 53 indicate, the federal government has systematically funded a large proportion of the total research and development effort in the nation for a considerable period of time.

TABLE 52

Intersectoral transfers of funds used for performance of research and development, basic research, applied research, and development: 1980 (estimated)

RESEARCH AND DEVELOPMENT[1]

[Dollars in millions]

Sources of funds	Performers						
	Federal Govern-ment	Industry[2]	Univer-sities and colleges[3]	Associated FFRDC's[4]	Other nonprofit institu-tions[2]	Total	Percent distribution, sources
Federal Government	$7,830	$13,950	$4,100	$2,000	$1,520	$29,400	48.7
Industry	—	[5]28,300	210	—	200	28,710	47.6
Universities and colleges	—	—	[5]1,300	—	—	1,300	2.2
Other nonprofit institutions	—	—	440	—	[5]525	965	1.6
Total	7,830	42,250	6,050	2,000	2,245	60,375	
			8.050				
Percent distribution, performers	13.0	70.0	10.0	3.3	3.7		100.0
			13.3				

BASIC RESEARCH[1]

[Dollars in millions]

Sources of funds	Performers						
	Federal Govern-ment	Industry[2]	Univer-sities and colleges	Associated FFRDC's[4]	Other nonprofit institu-tions[2]	Total	Percent distribution, sources
Federal Government	$1,210	$325	$3,100	$650	$450	$5,735	69.7
Industry	—	[5]1,000	125	—	95	1,220	14.8
Universities and colleges	—	—	[5]785	—	—	785	9.5
Other nonprofit institutions	—	—	265	—	[5]225	490	6.0
Total	1,210	1,325	4,275	650	770	8,230	
			4.925				
Percent distribution, performers	14.7	16.1	51.9	7.9	9.4		100.0
			59.8				

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[1] All data are estimated from reports by performers.

[2] Expenditures for federally funded research and development centers (FFRDC's) administered by both industry and by nonprofit institutions are included in the totals of their respective sectors. They are estimated to account for less than 5 percent and 15 percent, respectively, of the industry and nonprofit institutions performance totals. FFRDC's are organizations exclusively or substantially financed by the Federal Government tc meet a particular requirement or tc provide major facilities for research and training purposes.

SOURCE: National Science Foundation, Research and Development Expenditures, Washington, D.C., 1980 (draft).

TABLE 52 (Continued)

Intersectoral transfers of funds used for performance of research and development, basic research, applied research, and development: 1980 (estimated)—Continued

APPLIED RESEARCH[1]

[Dollars in millions]

Sources of funds	Performers: Federal Government	Performers: Industry[2]	Performers: Universities and colleges[3]	Performers: Associated FFRDC's[4]	Performers: Other nonprofit institutions[2]	Total	Percent distribution, sources
Federal Government	$2,520	$1,825	$825	$575	$550	$6,295	46.6
Industry	—	[6]6,300	75	—	65	6,440	47.7
Universities and colleges	—	—	[6]440	—	—	440	3.3
Other nonprofit institutions	—	—	140	—	[6]190	330	2.4
Total	2,520	8,125	1,480	575	805	13,505	
			2,055				
Percent distribution, performers	18.7	60.2	11.0	4.3	6.0		100.0
			15.2				

DEVELOPMENT[1]

[Dollars in millions]

Sources of funds	Performers: Federal Government	Performers: Industry[2]	Performers: Universities and colleges[3]	Performers: Associated FFRDC's[4]	Performers: Other nonprofit institutions[2]	Total	Percent distribution, sources
Federal Government	$4,100	$11,800	$175	$775	$520	$17,370	45.0
Industry	—	[6]21,000	10	—	40	21,050	54.5
Universities and colleges	—	—	[6]75	—	—	75	.2
Other nonprofit institutions	—	—	35	—	[6]110	145	.4
Total	4,100	32,800	295	775	670	38,640	
			1,070				
Percent distribution, performers	10.6	84.9	.8	2.0	1.7		100.0
			2.8				

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[3] Includes agricultural experiment stations.

[4] Federally funded research and development centers (FFRDC's) administered by individual universities and colleges and by university consortia.

[5] Includes State and local government funds.

SOURCE: National Science Foundation, Research and Development Expenditures, Washington, D.C., 1980 (draft).

TABLE 53

Sources of funds for research and development by sector: 1953 and 1960–80

[Dollars in millions]

Current dollars

Year	Total	Federal Government	Industry	Universities and colleges	Other nonprofit institutions
1953	5,124	2,753	2,245	72	54
1960	13,523	8,736	4,516	149	120
1961	14,316	9,250	4,757	165	144
1962	15,394	9,911	5,123	185	175
1963	17,059	11,204	5,456	207	192
1964	18,854	12,536	5,888	235	195
1965	20,044	13,012	6,548	267	217
1966	21,846	13,969	7,328	303	246
1967	23,146	14,395	8,142	345	264
1968	24,604	14,927	9,005	390	282
1969	25,631	14,895	10,010	420	306
1970	25,910	14,668	10,444	461	337
1971	26,604	14,892	10,822	529	361
1972	28,426	15,755	11,711	575	385
1973	30,631	16,309	13,294	615	413
1974	32,768	16,754	14,878	677	459
1975	35,256	18,152	15,820	750	534
1976	38,960	19,844	17,694	821	601
1977	43,013	21,751	19,696	893	673
1978	48,286	24,058	22,433	1,029	766
1979 (prelim) .	54,296	26,762	25,520	1,150	864
1980 (est.)	60,375	29,400	28,710	1,300	965

Constant 1972 dollars[1]

Year	Total	Federal Government	Industry	Universities and colleges	Other nonprofit institutions
1953	8,666	4,643	3,812	120	91
1960	19,649	12,681	6,578	215	175
1961	20,600	13,292	6,866	235	207
1962	21,768	14,000	7,261	259	248
1963	23,761	15,589	7,620	285	267
1964	25,859	17,174	8,097	320	268
1965	23,914	17,457	8,810	356	291
1966	28,444	18,183	9,547	394	320
1967	29,252	18,182	10,304	434	332
1968	29,825	18,103	10,906	474	342
1969	29,606	17,221	11,544	488	353
1970	28,400	16,090	11,433	507	370
1971	27,739	15,540	11,271	553	375
1972	28,426	15,755	11,711	575	385
1973	29,063	15,513	12,567	590	393
1974	28,476	14,647	12,826	601	402
1975	27,888	14,417	12,444	603	424
1976	29,165	14,865	13,234	617	449
1977	30,316	15,314	13,900	627	475
1978	31,756	15,822	14,754	677	503
1979 (prelim) .	32,823	16,185	15,420	696	522
1980 (est.)	33,264	16,215	15,799	718	532

[1] Based on GNP implicit price deflator.

SOURCE: National Science Foundation, Research and Development Expenditures, Washington, D.C., 1980 (draft).

A very large proportion of this has been for defense and space-related research and development activities, but civilian sector-related research and development funding by the federal government has increased from five percent in 1953 to an estimated 17 percent in 1980 (Table 54). These 17 percent of total federal research and development outlays represented, in 1979, almost $7.6 billion or 33 percent of the total expenditures for industrial research and development performance (Table 55). Table 60 indicates allocation of federal research and development funds by the industry sector.

As the data in Table 56 indicate, the federal government in recent years has accounted for about one-half of total research and development expenditures in the United States. About three-fifths of the federal government research and development expenditures are spent in defense and space-related activities, leaving only two-fifths for civilian-related research and development projects.

Industrial research and development expenditures were dominated by the private sector; in recent years this represented about 66 percent of total industrial research and development in the United States (Table 55).

TABLE 54

Trends in Federal and non-Federal R&D outlays: 1953 and 1960–80

[Percents]

Year	Federal				Non-Federal
	Total	Defense related	Space related	Civilian related	
1953	54	48	1	5	46
1960	65	52	3	9	35
1961	65	50	6	9	35
1962	64	48	7	10	36
1963	66	41	14	10	34
1964	66	37	19	11	34
1965	65	33	21	11	35
1966	64	33	19	12	36
1967	62	35	14	13	38
1968	61	35	13	13	39
1969	58	34	11	13	42
1970	57	33	10	14	43
1971	56	32	9	15	44
1972	55	32	8	15	45
1973	53	31	7	15	47
1974	51	28	7	16	49
1975	51	27	7	17	49
1976	51	26	8	17	49
1977	51	25	8	18	49
1978	50	24	7	19	50
1979 (prelim.)	49	24	7	18	51
1980 (est.)	49	24	8	17	51

NOTE: Detail may not add to 100 because of rounding.

SOURCE: National Science Foundation, Research and Development Expenditure, Washington, D.C., 1980 (draft).

TABLE 55

Funds for industrial R&D performance by source: 1968–79

[Dollars in millions]

Year	Total R&D		Federal			Company		
	Current dollars	Constant 1972 dollars[1]	Current dollars	Constant 1972 dollars[1]	Percent of total	Current dollars	Constant 1972 dollars[1]	Percent of total
1968	17,429	21,108	8,560	10,366	49	8,869	10,741	51
1969	18,308	21,112	8,451	9,745	46	9,867	11,366	54
1970	18,062	19,770	7,779	8,514	43	10,283	11,255	57
1971	18,311	19,070	7,666	7,984	42	10,645	11,086	58
1972	19,539	19,539	8,017	8,017	41	11,522	11,522	59
1973	21,233	20,069	8,145	7,698	38	13,088	12,371	62
1974	22,867	19,710	8,220	7,084	36	14,647	12,624	64
1975	24,164	19,000	8,605	6,768	36	15,559	12,227	64
1976	26,938	20.139	9,561	7,148	35	17,377	12,991	65
1977	29,933	21,123	10,525	7,427	35	19,408	13,697	65
1978	33,406	21,970	11,301	7,432	34	22,105	14,538	66
1979 (est.)	37,700	22,765	12,550	7,579	33	25,150	15,200	67

[1] Based on the GNP implicit price deflator.

SOURCE: National Science Foundation, Research and Development Expenditures, Washington, D.C., 1980 (draft).

TABLE 56

Federal funds for industrial R&D performance by industry: 1968-78

Industry	SIC code	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
Total		8,869	8,451	7,779	7,666	8,017	8,145	8,220	8,805	9,561	10,525	11,301
Food and kindred products	20	182	1	3	2	1	1	1	(1)	(1)	(1)	(1)
Textiles and apparel	22,23	(1)	(1)	(1)	1	1	1	(1)	(1)	(1)	(1)	(1)
Lumber, wood products, and furniture	24,25	20	0	0	(1)	(1)	(1)	(1)	0	0	0	0
Paper and allied products	26	(1)	(1)	(1)	(1)	2	(1)	(1)	(1)	(1)	(1)	(1)
Chemicals and allied products	28	1,389	192	180	184	189	203	214	236	266	299	361
Industrial chemicals	281-82,286	810	165	158	159	171	183	194	218	249	277	338
Drugs and medicines	283	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)
Other chemicals	284-85,287-89	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)
Petroleum refining	29	403	10	22	17	15	14	20	(1)	52	76	119
Rubber products	30	186	65	71	69	123	146	(1)	(1)	(1)	(1)	(1)
Stone, clay, and glass products	32	139	1	11	10	14	15	14	(1)	(1)	(1)	(1)
Primary metals	33	241	10	10	6	12	11	8	21	26	24	28
Ferrous metals and products	134	2		1	2	3	4	(1)	3	4	4	5
Nonferrous metals and products	333-36	108	9	9	4	10	7	(1)	17	22	20	23
Fabricated metal-products	34	165	8	7	11	12	13	14	27	36	45	36
Machinery	35	1,142	260	262	315	401	429	511	509	532	569	582
Office, computing, and accounting machines	357	(1)	(1)	(1)	(1)	(1)	(1)	(1)	486	509	546	552
Other machinery, except electrical	35 Balance	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	23	30
Electrical equipment	36	1,749	2,390	2,211	2,258	2,367	2,410	2,307	2,307	2,555	2,693	2,976
Radio and TV receiving equipment	365	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	0	0	0
Electronic components	367					125	146	184	(1)	(1)	(1)	(1)
Communication equipment	366	993	1,557	1,420	1,479	1,417	1,362	1,137	1,057	1,093	1,202	1,372
Other electrical equipment	361-64,369	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)
Motor vehicles and motor vehicles equipment	371					293	385	288	318	383	438	349
Other transportation equipment	373-75,379	1,124	290	314	309	26	39	47	47	(1)	(1)	(1)
ircraft and missiles	372,376	1,230	4,524	4,005	3,864	3,970	3,899	4,000	4,428	4,921	5,526	5,821
rofessional and scientific instruments	38	429	237	194	164	161	160	167	172	183	159	174
Scientific and mechanical measuring instruments	381,82	83	32	20	14	13	11	10	15	15	10	10
Optical, surgical, photographic, and other instruments	383-87	346	205	174	150	148	149	157	157	148	149	164
ther manufacturing industries	21,27,31,39	(1)	(1)	(1)	(1)	(1)	(1)	(1)	7	5	5	9
onmanufacturing industries	07-17,41-67,737 739,807,891	172	448	480	452	431	416	463	310	375	466	547

Not separately available but included in total.
Data not tabulated at this level prior to 1972.
Data not tabulated at this level prior to 1977.

SOURCE: National Science Foundation, Research and Development Expenditures, Washington, D.C., 1980 (draft).

In dollar terms in the year 1978, total industrial research and development expenditures in the U.S. were almost $33.4 billion, of which industry funded $22.1 billion and federal government $11.3 billion. However, federal government industrial research and development expenditures were not evenly distributed among all sectors of the economy. Rather, two specific sectors -- electrical equipment and aircraft and missiles -- accounted for $8.8 billion or 78 percent of the $11.3 billion (Table 56).

Clearly, the federal government, because of its significant funding of industrial research and development projects, has considerable leverage in selecting research and development goals and objectives and, therefore, also in selecting research and development activities directed towards the development of specific end-product substitutes.

As noted, however, the private sector contributes about 66 percent of industrial research and development expenditures, and the federal government research and development expenditures for industrial purposes are concentrated in a few sectors of the economy. Nevertheless, while federal government's research and development funding may have significant impact on development of end-product substitutes, unfortunately there are no data which would provide additional information on this.

Federal Procurement Policies

Federal procurement policies have considerable impact on any one end-product because such procurement assures a firm or firms manufacturing specific end-products of a significant market or demand. This is of special importance in the initial production period of any end-product when the unit production costs are high. An excellent example of the impact of government procurement on the development of an end-product can be seen in the case of 4K RAMS, a specific type of semiconductor device used in numerous civilian and military applications. In the year 1957, when the 4K RAM was developed, the cost of this semiconductor device was over $1.75 per unit. The Department of Defense purchased about 45 percent of the total annual output of this device (and 35 percent of each of the following five years), allowing the industry to reduce the cost to less than $0.10 per unit, at which point the civilian sector began to use this particular semiconductor. By the year 1977, the civilian sector demand for the total annual production of this device was so great that civilian consumption exceeded 90 percent of production.[1/]

1/ Charles River Associates, The Effect of Government Policy on Innovation, Competition, and Performance: A Case Study of the Semiconductor Industry, Boston, Massachusetts, 1980.

Another example of the impact of federal procurement policies on end-product substitution can be seen in the case of cadmium use in electroplating. As discussed in another section of this report, the Department of Defense procurement specifications have been one of the principal reasons for the slow pace at which cadmium has been substituted by other metals in the electroplating industry.

Clearly, federal government procurement policies have had significant impact on the use, production and markets for many end-products and/or their substitutes.

Trade Policies

Federal government trade policies have an impact on end-product substitution because international trade may expand the markets for certain end-products and therefore assure larger demand, limit the domestic market because of imports, or assure that substitutes for certain end-products are available as a result of imports.

One additional issue may arise as a result of federal trade policies -- namely, that of how to handle the situation involving an end-product which is replaced in U.S. manufacturing because of hazardous waste generation but which continues to be manufactured and then imported to compete with the substitute end-product.[1/]

[1/] On this, see: OECD, Working Paper on International Trade and International Production. Paris, France, 1981.

In such a case, the substitute end-product may experience limited domestic demand because of competition from the imported original end-product.

Clearly, the principal impact of government's trade policies on the end-product substitution takes place when government uses the available regulations to encourage exports of certain end-products and by doing so, expands the demand for certain end-products at the expense of other end-products.

Specifically, there are two such mechanisms: DISC and the Export-Impact Bank. DISC (Domestic International Sales Corporation) allows domestic companies that engage in international trade to reap tax advantages on some of their international transactions as if they owned foreign subsidiaries rather than exported from domestic plants. DISC provides an incentive for firms which do not have the resources to set up foreign subsidiaries to nevertheless engage in international trade and export their products. As a result, firms may alter their strategies and begin to market products abroad. This may divert (at least temporarily) some resources from domestic operations and away from ongoing research and development, possibly for substitute end-product development.However, by exporting and marketing new products abroad, the transfer of information and technology will be hastened, thus improving general worldwide economic performance.

The Export-Import Bank encourages firms to export products by providing credits and guaranteed loan programs[1] to foreign buyers. The Eximbank also has several supplier credit programs[2] aimed at facilitating and stimulating U.S. exports. These policies again may result in market expansion of certain end-products at the expense of other end-products.

Tax Policies

As already noted, a successful end-product substitution requires significant research and development expenditures and the desire by a firm to innovate. It has been alleged that some of the U.S. tax policies have diminished the incentives for firms to innovate.

Up to the year 1969, tax policies had little direct impact on firms. Then the tax rate on capital gains was increased from 25 percent to almost 50 percent (over a period of three years). A series of other changes followed.[3] Many of the executives of U.S. firms assert that changes in tax policies in the last 12 years have made capital more difficult to obtain and have restricted the ability of firms to expand capacity, enter new product areas, and grow at historical rates.[4]

1/ The buyer credit programs include financial guarantees, participation financing, and cooperative financing.

2/ Supplier credit programs include guarantee of receivables, contract guarantees, and guarantees of bank-to-bank lines of credit.

3/ These pertained to: investment tax credit; depreciation rules; issues related to capital gains tax; and issues related to treatment of stock options.

4/ See for example: E.H. Mantell, "The Effects of Tax Exemption of Capital Gains on Demand for Rising Investments", Quarterly Review of Economics and Business, Winter 1975, 15(9) and K.B. Bhatia, "Corporate Taxation, Retained Earnings, and Capital Formation" Journal of Public Economics, February 1979, 11(1).

Several tax policies (Investment Tax Credits, depreciation laws, capital gains, taxation of stock options, and other tax credits) are described below to point out the various effects they have had on capital formation, entry of new firms (i.e., venture capital availability) and incentives to invest in research and development. Each of these tax policies is general in nature, that is, it affects firms in all industries.

Investment Tax Credit

The Investment Tax Credit[1] is available for investments in machinery and equipment, but not for buildings or research and development, and is currently set at a rate of 10 percent. Uncertainty about the Investment Tax Credit has existed since it was introduced in the early 1960's and used in varying degrees as a countercyclincal device. Until 1978,[2] it was a temporary measure that was adjusted (or abolished) as policy makers believed economic conditions warranted. Several studies have indicated that it may be a useful and effective incentive for business investment and that it promotes faster, long-term growth in the capital stock.

1/ The Investment Tax Credit is a reduction in tax liability equal to 10 percent of the firm's investment in machinery and equipment.

2/ The Revenue Act of 1978 made the Investment Tax Credit permanent, thus removing some of the uncertainty about the policy.

The Investment Tax Credit may affect the firm's financial structure by providing an incentive to invest in assets that qualify for the tax credit (sich as equipment and machinery). This, in turn, may influence a firm's strategies; expansion of capacity may allow a firm to move into new product areas (for example, in substitute end-products) since the credit can be applied to the equipment needed to expand capacity.

Innovative behavior may leave firms with more funds to invest in research and development. The stated purpose of the Investment Tax Credit is to improve economic performance by increasing productivity, creating jobs, and providing capital for expansion. Technological innovation may also occur indirectly as a result of the increases in research and development investments. Applications of the Investment Tax Credit to research and development expenditures is currently an important issue and is viewed as one way of "staying even" with foreign government incentives to their firms.

Depreciation Rules

Another policy issue is the rate at which the Internal Revenue Service allows firms to depreciate their plant and equipment. The rate of depreciation will affect when a firm decides to replace old equipment with new machinery. Underdepreciation will delay this replacement decision and may reduce productivity. Perhaps more important to the industry is the rapid rate of obsolescence of equipment due to technological change and the need for rapid write-off to spur firms to replace obsolete

The third component, reduction in maximum tax benefits on personal service income, contributed as much as 10 points to the taxes on capital gains. Since 1971, it has applied to the individuals who are in the highest tax bracket and who have some form of labor income (Section 1348 of the Internal Revenue Code).

The Tax Reform Act of 1976 also lengthened the minimum holding period requirement for qualifying capital gains. This period went from six months in 1976, to nine months in 1977, and to twelve months in 1978 (Section 1222 of IRC).

Many economists, businessmen, and Congressmen expressed concern that these changes would stifle capital formation, slow growth and productivity, and prevent new, small firms from raising investment (venture) capital.[1] This latter issue, the ability of firms to raise capital, had the greatest impact on industry.[2] Because of the increased capital gains tax rate in 1969, individual investors in new companies did not have an incentive to invest in a new venture unless the prospective returns were quite high. Venture capitalists viewed the investment decision in terms of a risk-return tradeoff, and the increase in capital equipment and prevent the taking of large losses. A more rapid rate of depreciation would give firms a stronger incentive to keep up with new technology and to replace old equipment more rapidly. As improvements in process equipment occur, various manufacturers would have a greater incentive to install this equipment immediately.

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[1] See: R.C. Osborn, "Providing Risk Capital for Small Business: Experience of the SBIC's", Quarterly Review of Economics and Business, Spring 1975, 15(1).

[2] On this, see: J.C. Fellingham and M.A. Walfson, "The Effects of Alternative Income Tax Structure on Risk Taking in Capital Markets", National Tax Journal, December 1978; W.C. Melton, "Corporate Equities and the National Market System," Federal Reserve Bank of New York Quarterly Review, Winter 1978-1979.

Capital Gains Tax

The capital gains tax created a great deal of controversy among various industry executives during the 1970's. Between 1969 and 1976, there was a general tendency in Congress to increase the effective tax rate on capital gains. The net effect was to increase the maximum rate from 25 percent in 1969 to almost 50 percent in 1978. The Tax Reform Act of 1978 then reduced this maximum rate to 28 percent.

Prior to the Tax Reform Act of 1978, there were three components to the capital gains taxes: a standard capital gains tax, a minimum tax, and maximum tax benefit on personal service income. The standard capital gains tax rate (Section 1202 of the Internal Revenue Code) was increased by the Tax Reform Act of 1969 from 25 percent in 1969 to 29.5 percent, 32.5 percent, and 35 percent in the three following years. For taxpayers in the highest tax brackets, the minimum tax contributed close to 5 points to the overall tax rate on capital gains.

gains tax acted to decrease the prospective rewards of any venture capital investment.[1] Thus, individuals had an incentive to invest their capital elsewhere, probably in a less risky venture where the return, although diminished by the increased taxes, would be more certain.

Venture capital has played an important role in industry[2] and it is worthwhile examining how policies (especially the change in capital gains tax) have affected its availability. Venture capital availability in every industry will fluctuate over time depending on general economic conditions and business cycles. Nevertheless, venture capital will be more readily available to firms in a rapidly growing industry, as opposed to more mature, slower growing industries. In the former industry, the risk/return tradeoff often appears more attractive, especially during boom economic conditions. In a strong economic environment, the venture capital market is usually very active; however, capital "dries up" during downturns and it becomes more difficult to obtain money for a new venture.

However, in the late 1960's and early 1970's, venture capital became more difficult to raise for new ventures. This was due, in part, to the change in the capital gains tax.[1] Thus, if the substitute end-product is manufactured by a new and/or small firm with limited access to capital markets, the provisions of capital gains tax are of critical importance.

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[1] A capital gain is defined as profits earned on the sale of capital assets held for twelve months or more. Thus, when a venture capitalist invests in a new firm, he expects a substantial return (usually 25 to 35 percent a year) on that investment that will be taxed as a capital gain once he liquidates that investment.

[2] See, for example: Eugene R. White, Testimony Before the Select Committee on Small Business; Venture Capital Availability and Related Issues, February 8, 1978.

Patent Policy

A patent is a grant of exclusive rights to the commercial sue of an invention. Patents may promote innovation by encouraging the introduction of a new substitute end-product; patents are intended to encourage commercialization and utilization of innovations such as substitute end-products and their disclosure to the public. Licensing of patents is a means of permitting the spread of information and use of new inventions while benefiting the inventor (through royalties or exchange of information).

Patents have been relatively unimportant to many industry sectors as a barrier to entry and mobility. For other sectors, patent policies have been of significant importance as they have been useful in disseminating technical information. A liberal attitude toward licensing arrangements has further encouraged commercialization of new developments and exchange of technical information.

1/ See: J.C. Francis, "Economic Pressures Reshape America's Stock Markets", Federal Reserve Bank Business Review, Philadelphia, June, 1973.

The rapid rate of technological change, the mobility of labor, and liberal licensing policies all have diminished the constraining impact of patents on industry. Nevertheless most firms have patented their innovations (both major and incremental innovations) and have formulated various strategies with respect to their use of patents and their willingness to license.

Patents and licensing agreements affect the environment in which a firm operates by increasing the stock of available technical knowledge, a factor of critical importance in substitute end-product development. The disclosure of proprietary information and the licensing of technology each increase available knowledge, which may enable others to make further innovations in substitute end-products.

Patents are a means for motivating engineers and researchers in substitute end-product development. Patents and bonuses based on them may be used by a firm as a reward for its staff members whose inventions contributed to a particular innovation. Another patent-related issue with regard to the end-product substitution pertains to the Federal Government's policies of Federal patents. Patents that result from research and development activities supported by Federal Government funding, i.e., so-called Federal patents, are not available for an exclusive use of a firm. Rather, such patents are available to all parties. This government patent licensing policy has made the use of such patents relatively unattractive.

There are proposals in the Department of Commerce[1] which will modify this government policy by allowing exclusive patent licenses to a firm on a basis of royalty payments for the use of the federal patent. This change, in turn, may facilitate the use of federal patents for the development and/or manufacture of substitute end-products.

Regulations Related to the Environment Quality

Capital investment for the abatement of air, water and solid waste pollution by manufacturing firms was estimated to be $37 billion in 1979, approximately 1.5 percent of the gross national product.[2]

1/ Interview with Robert Miki, Deputy Assistant Secretary for Regulatory Policy, Department of Commerce.

2/ Council on Environmental Quality, Environmental Quality, G.P.O., Washington, D.C., December 1980, p. 387.

During the period between the 1970-72 environmental legislation and the 1977 amendments, essentially all pollution abatement activities were undertaken using end-of-the-pipe treatment of wastes. In the 1977 amendments, the government has encouraged the use of other pollution abatement options.[1] In response to this encouragement, and also in order to constrain rapidly increasing pollution abatement costs, the industry has begun to utilize a number of options for pollution control other than end-of-the-pipe waste treatment.[2]

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[1] Perhaps the best indication of this encouragment can be seen in the various so-called "technology forcing" provisions in the 1977 amendments to the Clean Air and Water Acts. In the case of the Clean Air Act the relevant provisions are contained in Sections 3 (i) and 113 (d) (4). For water pollution abatement the principal "technology forcing" section is 301 (k). For detailed discussion on this see I. Gutmanic, et al., Report on Issues Related to Subsection 301 (k) of the 1977 Amendments to the CWA, by Sterling Hobe Corporation for the Environmental Protection Agency, October 1979; see also John E. Bonine, "The Evaluation of 'Technology-Forcing' in the Clean Air Act," Environment Reporter Monograph No. 21, Washington, D.C., Bureau of National Affairs, July 25, 1978.

[2] See for example: L.A. Abron-Robinson and E.J. Martin, Treatment Alternatives for Hazardous Waste Management in Nine Industry Groups, by Reer Consultants, Inc. for the Environmental Protection Agency, 1980, I. Gutmanis, et al., Case Studies of Innovation Water Pollution Control Technologies, by Sterling Hobe Corporation for the Environmental Protection Agency, December, 1979; A.K. Schwartz, Jr. and R.G. Thompson, An Integrated Power-Process Model of Water Use and Waste Water Treatment in Olefins Production, NSF (RANN) G1-34459-1 Technical Report, University of Houston, Texas, January, 1974; I.Gutmanis and S. Keehy, Water Use and Pollution in Textile Industries, for Resources for the Future, Inc., Washington, D.C. 1978 and personal communication with William Richard, Manager, Maleic Anhydride Production, Monsanto Corporation. This technology change consists of altering raw material inputs from benzene to butane. Also personal communication with John B. Crowell, Jr., Genera Counsel for Louisiana-Pacific Corporation regarding in-plant modifications to reduce wastewater volume at Ketchikan Pulp.Co.

Essentially, there are three alternatives to the end-of-the-pipe waste abatement that are used by industry. These are:

1. alternatives in technology;
2. alternatives in raw materials and fuels; and
3. alternatives in end-products produced.

The latter alternative is, of course, of specific interest here. There are no environmental regulations which explicitly mandate end-product substitution as a result of environmental considerations.

End-product substitution, as a means to achieve reduction in hazardous waste generation is, however, encouraged in so-called "technology forcing" provisions of the environmental legislation.1/ Up to the present time (summer of 1981), no firm has proposed to utilize end-product substitution under the "technology forcing" provisions of either the Clean Water or Clean Air Acts.2/

The principal reason for this lies in the complexity of regulations which govern the "technology forcing" provisions of these two Acts.3/

1/ See: I. Gutmanis, Report on Issues Related to Subsection 301(k) of 1977 Amendments to the CWA, for EPA, Sterling Hobe Corporation, 1979.

2/ Except for substitution of pesticides described in the following section.

3/ Among these complexities are the following: requirement that any innovation leading to end-product substitution be available for the entire industry sector; requirement that specifies that the innovation result in "significant" energy savings, without providing definition of the term "significant"; requirement that the innovation be "readily" transferable to other sector of economy; and requirement that apparently prohibits patents for innovations which qualify under "technology forcing" provisions of the two Acts.

Conclusions

As described above, most, if not all, government policies and regulations affect end-product substitutions either directly or indirectly, even when such policies and regulations are not enacted explicitly for the purpose of either promoting or retarding end-product substitution.

Often, end-product substitution is a result of government policies and/or regulations enacted in order to achieve other goals and objectives.

For example, the federal government's desire to conserve energy and, more specifically, gasoline, have resulted in series of so-called CAFE (i.e., sales-weighted Corporate Average Fuel Economy) regulations which require achievement of certain minimum miles per gallon fuel efficiency. This, in turn, already has (and will even more in the future) resulted in significant substitution of the materials currently used in motor vehicles by new materials which are lighter than those they replaced, reducing the weight of the motor vehicle and improving fuel efficiency.

In order to show the magnitude of this material substitution induced by a government regulation directed at a national goal of energy conservation clearly some distance removed from policies related to end-product substitution, it is useful to quote from a recent article published in The Economist magazine:[1/]

[1/] "World Motors, A Survey", The Economist, December, 1980.

Not surprisingly, Detroit executives talk incessantly about "down-sizing". They really mean "down-weighting". The work has stuck because the first attempt to make the traditional piece of Detroit ironmongery lighter was simply to chop a foot or two off its length. General Motors' president, Mr. Pete Estes, has pointed out:

> Since 1974, we have reduced the sales-weighted average weight of our cars by 650lb. We need to get another 700lb. out of them on average by 1985.

Much the same story is repeated across the street
hrysler and over at Ford.
he next round of weight-saving, however, will
come so easily. It is going to require real
neering, especially in learning how to use
nforced plastics, aluminium alloys and high-
ength steel in place of conventional materials.
ineers reckon that, keeping the car roughly
e same shape and size, it should be possible to
duce its weight by 20% solely by using lighter
terials. That means as much as 800lb could
eoretically be saved on a typical 4,000lb car
y replacing many of its cast iron and sheet
teel parts with aluminium and plastic ones.
That, however, is probably asking a bit too
uch of the production engineers. Chrysler's
Mr. Heinen believes that somewhere around 500lb
would be a more realistic estimate. He says: "We're bound to run into technical and economic problems with materials like aluminium and plastic."

Some of the savings in weight already being engineered sound trivial. But every ounce counts. For instance, chrome-plated bumpers stamped out of aluminium instead of steel are nearly twice as strong and almost 60lb lighter. Stamped aluminium wheels save 32lb per car. Intake manifolds made in two parts from die-cast aluminium instead of cast iron and welded together (ingeniously but expensively) by an electron beam save 14lb. An aluminium compressor for an air conditioning unit saves 13lb. More sheet plastic is also creeping into cars--at the moment largely for unstressed parts like trunk (boot) lids or front fairings. High-strength steel, two to three times stronger than ordinary steel, is being used to make thinner and lighter axles, suspension arms and reinforcing beams. Even the thickness of the window glass has been shaved a millimetre or so to save weight.

> In their haste to catch up in designing light cars, Detroit's engineers are constantly reinventing the wheel. Take, literally, the wheel. The spare accounts for about 50lb of dead weight. As it is needed only for emergencies, manufacturers have begun to make it thinner. Their next step will be to remove it altogether. That will mean developing tyres that can run flat or repair themselves. Such tyres already exist in Europe.

As the above clearly shows, federal government's regulation of reducing sales-weighted average weight of passenger vehicles has resulted in a host of car components substitutions.

Note that the government's regulation is one of performance standards, i.e., reduction in weight (rather than design standards) which leaves the specifics as to how this performance is to be achieved to the private sector. Such an approach may, of course, be used also in hazardous waste management policy. In this case, the government would issue a regulation which would limit to certain selected levels the emissions of hazardous wastes into the environment for a selected number of specific hazardous compounds and allow the private sector to undertake whatever actions are required to achieve these emission levels.

In order to be economically effective such government policy should cover the emissions of the selected hazardous compounds throughout the entire life cycle of the product which is associated with the emissions of the hazardous wastes, i.e., from the manufacture to the use to the ultimate final disposal of the product. Under such regulation, the entire responsibility to meet the selected levels of the permissable emissions will rest exclusively with the manufacturers of products associated with hazardous waste emissions because there are no practical mechanisms which would allow the manufacturer to exercise any meaningful control over the product over the life cycle of the product, i.e., during its use and at the time of the product's ultimate final disposal.

This, in turn, means that the end-product substitution alternative (as compared to process technology change) to - hazardous waste emission control will become the dominant strategy by those manufacturers of end-products which generate hazardous wastes during their life cycle after the manufacture. The principal difficulty with such a regulation is that it is difficult to select conceptually and empirically appropriate base units against which the permissible emissions levels of hazardous wastes are measured.

In the case of passenger cars, the base unit against which the weight reductions are measured is the sales-weighted average weight of passenger cars. To apply this notion to all products which are associated with hazardous waste emissions is not practical because of the very large number of such products. Such regulation would also require very large administrative expenditures by the federal government.

From an environmental point of view, an attractive base unit against which all hazardous waste emissions can be measured could be the total level of each type of hazardous waste permitted to be emitted into the environment per unit of time, e.g., annually.

The problem with this approach lies in the difficulties to allocate the total permissible hazardous waste emissions among products associated with such wastes and/or firms which manufacture such products.

However, if an appropriate, impartial and fair allocation could be achieved, this approach would result in economic efficiency providing permission would be granted to firms which manufacture products associated with hazardous waste to sell and buy the right to emit hazardous wastes up to a certain level.1/

EPA Pesticide Cancellation/Suspension: A Survey of Economic Impacts

About 1.1 billion pounds of pesticides are used annually in the U.S., at a user cost of about $5 billion. More than 30 thousand pesticides products containing 1,400 active ingredients are registered with EPA for use against 21,500 pest species.

1/ This approach is essentially that used in "bubble" and "Trade-off" concepts by EPA.

The purpose of this section is to summarize the economic impacts of nine major pesticide cancellation/suspension actions taken by EPA since this Agency was formed in December, 1970. The nine pesticide cancellations are as follows: DDT Cancellation - 1972; Aldrin/Dieldrin Suspension - 1974; Chlordane/Hepachlor Cancellation/Suspension - 1974/1975; Mercury Cancellation - 1976; Chlorobenzilate Cancellation - 1979; DBCP Suspension/Cancellation - 1977/1979; Endrin Cancellation - 1979; Kepone Cancellation - 1978; and 2,4,5-T/Silvex Suspension - 1979. Estimates of economic impacts (e.g., cost and market production/price effects) are made for each regulatory action for a typical year[1/] after the regulatory action becomes fully effective. Long term estimates are also made for the anticipated period of impact. The long term estimates are straight line projections and assume that impacts would decline from the midpoint of the projected range in the initial short term annual impacts to negligible levels after four to ten years. This method was adopted to reflect trends in such factors as: declining use of the problem chemicals due to emergence of pest resistance; development of substitutes (which takes about seven years from discovery); and improved use of pest control technology due to integrated pest management projects and applicator training.[2/]

[1/] Normally, two or three years after regulatory action becomes effective.

[2/] Arnold L. Aspelin, Economic Testimony in Chlordane/Heptachlor Suspension Hearings, Exhibit S-26, Washington, D.C., September 1975. (see: EPA, Actions to Cancel and Suspend Uses of Chlordane and Heptachlor as Pesticides - Economic and Social Implications, EPA-540/4-76-004, U.S. Environmental Protection Agency, Washington, D.C., August 1976, Part II).

The nine major pesticide cancellation/suspension actions described here have involved 12 of the 1,400 EPA registered active ingredient pesticides and about 80-95 million pounds of active ingredients used per year (7-8 percent of U.S. total). The total projected direct economic impact of these actions is about $363 million ($1.65/capita) over the period during which impacts are expected to occur (through about 1990).[1/]

As will be discussed below, most, if not all, of the cancelled pesticides have substitutes. While some of these substitutes are more costly and/or not as effective, their availability significantly mitigates the EPA's cancellation of several major pesticides used in the agricultural sector. However, pesticide cancellation does have some impact on this sector.

These impacts, while significant, are nominal compared with the overall cost of pollution abatement programs in the U.S. which has been estimated to be about $500 billion over the ten year period 1978 to 1988. This overall cost approaches $2,300 per capita, compared with about $1.65 per capita for major pesticides actions.[2/]

[1/] Arnold L. Aspelin, et al., EPA Pesticide Cancellations and Suspensions: A Survey of Economic Impacts, Office of Pesticide Programs, EPA, March 1980.

[2/] See: Asperlin, Arnold L., et al., op. cit.

Note that the "benefits" and "costs" estimates on a per capita basis have been shown in order to provide common bases for these estimates. It would be very useful to show the impacts, i.e., costs on basis of pesticide industry and/or per employee in this industry. Unfortunately, there are no data which would permit such calculations.

DDT Cancellation [1]

DDT, for many years one of the most widely used pesticides in the U.S., was cancelled for most of its remaining uses, effective January 1, 1973. DDT had been widely used since World War II, reaching a peak of nearly 80 million pounds per year in the late 1950's. By the early 1970's, its use had declined greatly -- to 14-20 million pounds per year. Most U.S. production of DDT at that time was, and continues to be, for export. By 1972, DDT was the fourth ranking insecticide used in the U.S. in terms of active ingredients.

Cost impacts of the cancellation were quite significant in the South Atlantic Region where most of the DDT was used on cotton, as production costs increased by $630 per farm on the average for 9,500 farms in 1973 and 1974. Cotton insecticide costs in this region were increased, due to the DDT cancellation, by $6.22 per treated acre, over the 1971/72 average of $15.51 per acre. Effects on insecticide costs in the East South Central Region were much less, only about $0.28 per treated acre. The cost impacts totalled $7.75 million, nationally, equaling slightly

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1/ All figures used in this section have been obtained from: U.S. Environmental Protection Agency, DDT: A Review of Scientific and Economic Aspects of the Decision to Ban Its Use as a Pesticide, Washington, D.C., July 1975; and, U.S. Environmental Protection Agency, Briefing on DDT: A Review of Scientific and Economic Aspects of the Decision to Ban Its Use as a Pesticide, prepared for the Committee on Appropriations, U.S. House of Representatives, Washington, D.C., July 1975.

more than $1.00 per acre of cotton treated with insecticides (all types) or an increase in total cotton production costs of 0.5 percent.[1]

Based on a linear programming analysis,[2] the impacts of the cancellation on cotton producers' costs are not projected to generate large regional or national effects in cropping patterns for cotton and other major agricultural crops. Thus, the major economic impact of the cancellation of DDT use on cotton was to increase production costs in the Southeastern U.S., causing cotton to be somewhat less profitable for affected growers. Cotton production has been maintained adequately to meet market needs since the DDT cancellation, although yields may have been affected to some extent.[3]

The cancellation of other crop uses of DDT has been of minor significance. The increased cost of shifting to alternative controls for these uses was estimated to be $460,700 nationwide.[4]

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[1] U.S. Environmental Protection Agency, DDT: A Review of Scientific and Economic Aspects of the Decision to Ban Its Use as a Pesticide, Washington, D.C., July 1975.

[2] Ibid.

[3] U.S. Environmental Protection Agency, Briefing on DDT: A Review of Scientific and Economic Aspects of the Decision to Ban Its Use as a Pesticide, prepared for the Committee on Appropriations, U.S. House of Representatives, Washington, D.C., July 1975.

[4] Ibid.

Production and yields of these other crops have been maintained without the use of DDT.

Overall economic impacts of the DDT decision are estimated to range from \$8.25 million to \$21.9 million, averaging \$15.07 million for a typical year immediately after cancellation and projected to decline linearly to negligible levels after about seven years. Total impact over seven years would be \$57.74 million (\$15.07 million x 7/2), equalling about 25 cents per capita.

Impacts of DDT Cancellation[1]

A. REGULATORY ACTION	Cancellation of remaining major uses of DDT (primarily cotton) and most minor uses, effective January 1, 1973.
B. EXEMPTIONS:	Certain minor crop uses without substitutes (temporary, pending determination on availability of substitutes) and public health/quarantine uses by official government agencies. Forest use was not addressed in the DDT hearings--use phased out earlier by USDA.
C. EXTENT OF DDT USE:	
Cotton:	S.E. U.S., only; 17% of U.S. cotton farms; 25% of U.S. cotton acres; 20 and 60 percent of cotton farms in two S.E. U.S. regions, respectively (18,700 farms); 12-16 million lbs active ingredient/yr.
Other agric. uses:	Primarily peanuts, soybeans, potatoes and other vegetables; 1-2 million lbs active ingredient/yr; less than 3% of U.S. acreage.

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[1] See: Arnold L. Aspelin, et al., EPA Pesticide Cancellations and Suspensions: A Survey of Economic Impacts, Office of Pesticide Programs, EPA, March 1980.

Other uses:	Industrial, governmental, home and garden; 1-[illegible] million lbs active ingredient/yr.
Total cancelled uses:	14-20 million lbs/yr. (equalling 4 to 5 percent of total U.S. insecticide use).
D. SUBSTITUTES	Generally available for all uses but often more expensive and may require more applications; yield effects are possible against some pests but not well documented; improved cultural practices, applicator training and integrated pest management programs minimize the need for chemical controls.
E. ECONOMIC IMPACTS:	
Cotton:	Cotton production costs increased $7.75 million/yr. in 1973 and 1974 (an average of about $400/farm in S.E. U.S.); also yield losses, although not clearly proven, are possible in the range of 0 to 4 percent on land where alternatives to not provide satisfactory performance (up to 31 million pounds, valued at $12.4 million at 1973 prices). Probable range in annual economic impacts - $7.75 million to $20.15 million (initial years of impact).
Other agric. uses:	$250.000 to $1.0 million/yr. (largely cost effects).
Non agric. uses:	$250,000 to $750,000/yr.
All cancelled uses:	Total impact of $8.25 to $21.9 million per year during initial years, declining to negligible impacts after about seven years.

Aldrin/Dieldrin Suspension and Chlordane/Heptachlor Cancellation/Suspension

EPA suspended food and feed use of aldrin and dieldrin in October 1974, after extended cancellation and suspension hearings. In November 1974, EPA cancelled chlordane and heptachlor uses with very minor exceptions. In December 1975, EPA suspended most uses of the chlordane/heltachlor compounds, pending the outcome of the cancellation hearings.[1] In March 1978, suspended uses of chlordane/heltachlor were cancelled, with a phase-out period in some instances. (For example, seed treatment uses are to be phased out by July 1, 1983.)

The full economic impacts of the suspension of aldrin and dieldrin used depends on whether chlordane/heptachlor is available as a replacement, and therefore economic impacts of actions involving aldrin/dieldrin and chlordane/heptachlor are estimated jointly. Detailed data on the use of these compounds and the estimated impacts of regulatory actions have been prepared by EPA economists and others testifying in public hearings.[2]

Corn was the largest agricultural use of these four insecticides, with 9.5 million pounds of active ingredients of

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1/ U.S. Environmental Protection Agency, EPA Actions to Cancel and Suspend Uses of Chlordane/Heptachlor as Pesticides: Economic and Social Implications, Washington, D.C., August 1976.

2/ Arnold L. Aspelin, Economic Testimony in Chlordane/Heptachlor Suspension Hearings, Exhibit S-26, Washington, D.C., September 1975. (See: EPA Actions to Cancel and Suspend Uses of Chlordane and Heptachlor as Pesticides -- Economic and Social Implications, EPA-540/4-76-004, U.S. Environmental Protection Agency, Washington, D.C., August 1976, Part II).

aldrin and dieldrin annually applied to 7 million corn acres (about 9.5 percent of the 1973/74 U.S. corn acreage). Chlordane and heptachlor were applied to 2 million corn acres in 1973/74 (about 1.5 percent of the domestic corn acreage).

Costs of meeting the domestic demand for corn and other major food/feed grains were estimated to increase by .06% or about $6.4 million annually after the regulatory actions are fully implemented. In addition to the above costs, an increased interregional transportation cost of $0.74 million was estimated for a typical year. The total cost impact to the corn sector for a typical year was estimated to be $7.14 million immediately following the full implementation of the regulatory actions. In a typical year, the total cost impact could vary from $5.0 to $10.0 million.

All other agricultural uses of aldrin, dieldrin, chlordane and heptachlor accounted for 3 to 4 million pounds of active ingredient. These uses were estimated to have annual production cost increases or yield losses ranging from $1.5 to $3.0 million.

The nonagricultural uses of these four insecticides accounted for 6 to 8 million pounds of active ingredient, which was mostly chlordane and heptachlor for termite control. The annual increase in pest control costs were estimated to range from $3.0 to $6.0 million.

The overall economic impact associated with regulatory actions taken against aldrin, dieldrin, chlordane and heptachlor were estimated to initially range from $9.5 to $19.0 million annually with a decline to negligible levels expected over a seven year time period. The total economic impact over the seven year period was estimated at $49.88 million or about 24 cents per capita.

Summary of Impacts of Cancellation/Suspension of Aldrin/Dieldrin and Chlordene/Heptachlor 1/

A. REGULATORY ACTION: Food and feed uses of aldrin/dieldrin (A/D) were suspended effective August 1974, as were similar uses of chlordane/heptachlor (C/H), effective July 1975.

B. EXEMPTIONS: Strucural termite uses were exempted from both actions; phase-out periods of use were authorized for several uses of C/H. The final phase-out dates range through July 1983.

C. EXTENT OF USE:

Corn: A/D - 7 mil acres/yr (9.5% of U.S. corn acres); 9.5 mil lbs; C/H - 2 mil acres/yr (1.5% of U.S. corn acres); 3 to 6 mil lbs; 1973/74 data.

1/ See: Arnold L. Aspelin, et al., EPA Pesticide Cancellations and Suspensions: A Survey of Economic Impacts, Office of Pesticide Programs, EPA, March 1980.

Other agric. uses: 3 to 4 mil lbs/yr.

Industrial/home garden & turf: 6 to 8 mil lbs/yr.

All suspended uses: A/D - 10 to 11 mil lbs/yr (about 3% of U.S. insecticide use).

C/H - 14 to 16 mil lbs/yr (about 5% of U.S. insecticide use).

Non-suspended uses: 6 to 8 mil lbs/yr - mostly C/H for termite use.

D. SUBSTITUTES: There are registered substitutes for all major suspended/cancelled uses of A/D and C/H but usually are somewhat more expensive (up to 50 percent in many cases) and may need to be repeated more often due to lack of persistence.

E. ECONOMIC IMPACTS: The A/D and C/H suspension actions are evaluated in combination because the two sets of active ingredients have overlapping uses and are ready substitues in many cases.

Corn: Costs of meeting domestic demand for corn and other major food/feed grain increased by 0.06% or $6.4 mil/yr after action would be fully in effect (early 1980's); to these costs are added $0.74 million per year in inter-regional transport costs giving total increase of $7.14 mil/yr for a typical year; costs could be greater or less in an individual atypical year during the initial years of suspension/cancellation, e.g., from $5.0 to $10.0 million.

Other agric. uses: Increased costs in yield losses ranging from $1.5 to $3.0 mil/yr.

Non-agric. uses: Increased costs of pest control ranging from $3.0 to $6.0 mil/yr.

All suspended uses: Total overall economic impact of $9.5 to $19.0 mil/yr, declining to negligible levels after a period of about 7 years. Total impact for 7 years is projected at $49.88 million.

3. Mercury Cancellation

EPA cancelled several major uses (paint, turf, and seed treatments) and most minor uses of mercurial fungicides and bactericides in early 1976. However, certain of these cancelled uses were reinstated later in the same year after further review pursuant to requests by industry and user groups.

In 1973, the largest cancelled use of mercurial pesticides was oil-base paint with 180,000 pounds of active ingredient. The cost impact associated with pain manufacturing ranged from 5.9 to 11.0 cents per gallon, which aggregated to a total annual impact ranging from $2.65 to $4.96 million for as many as 45.05 million gallons of oil-based paint affected by the cancellation.[1] The wide range of the annual impact results from differential uses of mercurials which are used either at relatively low concentrations as in-can preservatives or at higher concentrations as mildewcides, as well as the cost of alternative pesticides used.

The annual use of mercurial fungicides on turf for control of various summer grass diseases was about 43,600 pounds of active ingredient applied on approximately 8,125 golf courses. The annual cost increases associated with the maintenance of greens was estimated to range from $650,000 to $3,055,000. If this cost increase was totally passed on to 15.6 million golfers, the annual cost per golfer would increase within a range of 4.2 to 19.6 cents.[2]

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[1] Arnold L. Aspelin, et al., EPA Pesticide Cancellations and Suspensions: A Survey of Economic Impacts, Office of Pesticide Programs, EPA, March 1980.

[2] Ibid.

Mercurial seed treatments for fungal diseases were estimated to use 7,000 pounds of active ingredient annually. Annual regulatory cost increases were estimated to range from 7.1 to 38.8 cents per treated acre for 300,700 acres. The total annual impact was estimated to range from $21,000 to $117,000 or $38.80 for a farm that treated 100 acres.[1]

The overall annual economic impact associated with the cancelled uses of mercurial fungicides and bactericides was estimated to range from $2.65 to $4.96 million in the first two years following the regulatory action. The cost impact would increase to a range of $3.30 to $8.13 million following the imposition of the cancellation order on the use of mercurials for summer grass diseases of turf and seed treatments. The annual economic impact is expected to decline to negligible levels in about four years (totalling $11.4 million, or about 5 cents per capita).[2]

Summary of Impacts of Mercury Cancellation[3]

A. REGULATORY ACTION: Cancellation of the following pesticide uses of mercury; as an in-can preservative and/or mildewcide for oil-based paints (effective February 17, 1976); for seed treatments and summer diseases of turf after August 31, 1978, or following the production of two years supply of these products (based on recent production data) whichever occurs first; all uses of mercury in plastics and as medical disinfectants.

1/ See: Arnold L. Aspelin, et al., *EPA Pesticide Cancellations and Suspensions: A Survey of Economic Impacts*, Office of Pesticide Programs, EPA, March 1980.

2/ Ibid.

3/ Ibid.

B. EXEMPTIONS: Water-based paints, winter diseases of turf, textiles and fabrics for outdoor use, control of brown mold on freshly sawn lumber and Dutch elm disease.

C. EXTENT OF USE:

Oil-based paint: 180,000 pounds active ingredient mercurials were used in as many as 45.05 million gallons of paint/year (1973).

Turf, esp. golf courses for summer diseases: 43,600 pounds active ingredient mercurial fungicides were used on about 8,125 golf courses/year 1973.

Seed treatment: 7,000 pounds active ingredient used to protect various seeds from fungi.

D. SUBSTITUTES: A number of effective alternatives were available for most applications in which mercury pesticides have been used. For oil-based paint, mercury alternatives provide an adequate level of control at an increased cost ranging from 5.9¢ to 11.0¢ per gallon, depending upon the mercury substitute used. For turf the efficacy of nonmercurials (equal or superior to mercury compounds) has been indicated in the control of summer turf diseases, but are generally more expensive to use ($400 for the season per course). For seed treatments, the cost differential of nonmercurial over the mercurial compounds is slight, ranging from 7.1¢ to 38.8¢ per acre.

E. ECONOMIC IMPACTS:

Oil-based paint: Cost increased of 5.9¢ to 11.0¢ per gallon in as many as 45.05 million gallons; equivalent to an aggregate increase ranging from $2.65 to $4.96 million/year, depending upon the number of gallons treated and the alternative pesticide used.

Summer turf: Cost increase for control of summer disease of turf - 8,125 golf courses ranging from $650,000 to $3,055,555/year (4.2¢ to 19.6¢ more/year for 15.6 million golfers), after August 31, 1978, or after the production of two years supply of mercurial turf fungicides.

Seed treatment: Cost increase of 7.1¢ to 38.8¢ per acre on 300,700 acres, totalling $21,000 to $117,000 ($7.10 to $38.80 per farm on a farm with 100 acres treated).

Other uses: The use of mercurial compounds in other pesticidal applications (plastics and medical disinfectants) is minor. Subtitutes are available which have been used for years. Cancellation of other uses would have no measurable impact either on firms or on medical practice.

All cancelled uses: Total impact of $2.65 tc $4.96 million/year during thefirst two years of cancellation, increasing to $3.30 to $8.1 million/year following the imposition of cancellation upon summer turf disease uses (after August 31, 1978, or after two years' volume of production of mercurial turf fungicides). Impacts are expected to be negligible four years after effective cancellation.

4. Kepone Cancellation

EPA cancelled all registrations of products containing Kepone, effective May 1, 1978. Kepone use at the time of notice of cancellation was limited to the stock on hand of certain formulated products. The manufacturer of Kepone had previously ceased production and requested a voluntary cancellation of all Kepone registrations with the use of remaining stocks to be allowed. A review of the impacts of the cancellation action found that numerous substitute products were available at comparable costs to Kepone products.[1] No economic impacts were thus expected as a result of this cancellation action.

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[1] U.S. Environmental Protection Agency. Preliminary Benefit Analysis of Kepone for Control of Ants and Cockroaches in Domestic Dwellings. Economic Analysis Branch, CED, OPP. Washington, D.C., 1979.

Summary of Impacts of Kepone Cancellation[2]

A. REGULATORY ACTION: Cancellation of all registered products containing Kepone, effective May 1, 1978.

B. EXEMPTION: Use of existing stocks of all inaccessible products was permitted until such stocks are exhausted.

C. EXTENT OF USE:

Domestic dwellings: Approximately 1,000 lbs active ingredient remained when Allied Chemical Corp. ceased production with a request for voluntary cancellation provided use of existing stocks was permitted. A portion of the quantity in accessible devices was not allowed to be sold.

D. SUBSTITUTES: Numerous substitutes are available to replace Kepone. Substitutes are comparable or better in control and many have lower costs.

E. ECONOMIC IMPACTS: None.

1/ See: Arnold L. Aspelin, et al., EPA Pesticide Cancellations and Suspensions: A Survey of Economic Impacts, Office of Pesticide Programs, EPA, March 1980.

Chlorobenzilate Cancellation

In February 1979, EPA announced the intent to cancel all non-citrus uses of the miticide, chlorobenzilate. The uses to be cancelled included primarily the protection of cotton, fruits, nuts, melons, and turf grass. The cancelled uses accounted for about 120,000 pounds active ingredient out of the approximate total of 1.1 million pounds active ingredient of chlorobenzilate used annually. The remaining 1.0 million pounds active ingredient on non-cancelled uses are applied to citrus crops in Florida, California, Texas and Arizona.

All cancelled uses of chlorobenzilate have registered available alternative chemical controls.[1/] The use of these alternative chemicals is anticipated to maintain yield or mite control at the current levels. Production costs of some commodities may increase somewhat where alternatives are more costly to use. The total cost increase is expected to decline to negligible levels over a ten year span as new chemicals are developed for those uses. Economic impacts are not expected to be evident beyond the producer level because of the relatively minor extent of chlorobenzilate usage on the cancelled sites.

1/ . U.S. Environmental Protection Agency, Preliminary Benefit Analysis of Chlorobenzilate, Economic Analysis Branch, CED, OPP, Washington, D.C., 1977.

2/ Andrilenas, Paul and Eichers. Theodore, Evaluation of Pesticide Supplies and Demand for 1976, Agricultural Economic Report No. 322, Economic Research Service, U.S. Department of Agriculture, Washington, D.C., April 1976.

Summary of Impact of Chlorobenzilate Cancellation[1]

A. REGULATORY ACTION: Cancellation of registrations of chlorobenzilate for all uses other than citrus.

B. EXEMPTIONS: Registrations for citrus with modifications of terms or conditions of registration.

C. EXTENT OF CHLOROBENZILATE USE:

Other uses: Primarily cotton, fruits, nuts, melons, and turf grasses; about 120,000 lbs active ingredient applied over 24,000 acres.

Total cancelled uses: 120,000 lbs active ingredient.

Total non-cancelled uses: About 1.0 million lbs active ingredient used on citrus.

D. SUBSTITUTES: All cancelled uses have available alternatives with no yield changes anticipated. Changing to alternatives may increase production costs of individual commodities slightly.

E. ECONOMIC IMPACTS:

Other uses: Less than $200,000/yr. in increased cost of production.

All cancelled uses: Less than $200,000/yr.

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[1] See: Arnold L. Aspelin, et al., *EPA Pesticide Cancellations and Suspensions: A Survey of Economic Impacts*, Office of Pesticide Programs, EPA, March 1980.

Endrin Cancellation

In July 1979, EPA announced the intent to cancel registrations for use of the insecticide endrin on several sites. All other uses of endrin were continued with modifications to application instructions designed to minimize human and environmental exposure.[1]

The cancelled uses of endrin totaled about 600,000 pounds of active ingredient on an annual basis. The non-cancelled uses account for about 300,000 pounds active ingredient annually. The cancelled uses comprise about 0.2% of current insecticide use in the United States.

The cancelled uses of endrin generally have alternative chemicals available for use. Some increases in production costs for cotton and small grains are expected since some alternatives to endrin are higher in cost. The increases in production costs are $1.0 million and $1.2 million annually for cotton and small grains respectively. The development of new chemicals and the possibility of resistance to endrin on the part of some pests leads to the assumption that the effect of the cancellation on production costs would decline to negligible levels over a seven year period from the effective date of cancellation. The total impact would thus be about $7.7 million. Economic impacts are not expected to be evident beyond the user level.

1/ U.S. Environmental Protection Agency, Preliminary Benefit Analysis of Endrin, Economic Analysis Branch, CED, OPP, Washington, D.C., 1977.

Summary of Impacts of Endrin Cancellation[1]

A. REGULATORY ACTION: Cancellation of the use on cotton in certain areas use on small grains to control all pests other than army cutworm, the pale western cutworm, and grasshoppers; use on apple orchards in Eastern states to control meadow volesl use on sugarcane to control sugarcane borer, and use on ornamentals.

B. EXEMPTIONS: Remaining uses with modifications to terms and conditions of registrations including: use on cotton west of Interstate Highway #35; use on small grains to control army cutworms and pale western cutworms; use on apple orchards in Eastern states to control pine vole and in Western states to control meadow vole; use on sugarcane to control sugarcane beetle; use for conifer seed treatment, and use in enclosed bird perch treatments.

C. EXTENT OF ENDRIN USE:

Cotton: About 600,000 lbs. active ingredient, primarily in combination with methyl parathion, largely east of Interstate #35.

Small grain: Cancelled uses on small grains total about 1,500 lbs active ingredient.

Apple orchards: Cancelled uses will have no appreciable impact on endrin use on this site.

Other uses: All other cancelled uses would total less than 1,000 lbs. active ingredient.

Total cancelled uses: Slightly more than 600,000 pounds active ingredient.

Total non-cancelled uses: About 300,000 lbs. active ingredient on small grains and about 1,500 lbs. active ingredient for other uses including forest forest seed treatment and bird control.

D. SUBSTITUTES: Alternatives are generally available for significant cancelled uses of endrin.

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[1] See: Arnold L. Aspelin, et al., EPA Pesticide Cancellations and Suspensions: A Survey of Economic Impacts, Office of Pesticide Programs, EPA, March 1980.

E. ECONOMIC IMPACTS:

Cotton:	The cancelled uses on cotton will have small impacts on growers with and expected impact of $2.0 million increase in production costs.
Small grains:	Cancelled uses on wheat will cause negligible increase in production costs as a result of switching to higher cost alternatives.
Apple orchard use:	The cancelled uses on apple orchards will result in no expected losses and negligible cost increases.
Other uses:	No expected impacts for other cancelled uses.
All cancelled uses:	Total impact of up to $2.2 million during initial years, declining to negligible levels after about seven years.

7. DBCP Suspension and Cancellation

From September 1977 through October 1979, several notices of intent and orders of cancellation and suspension were issued by EPA concerning the nematicide DBCP. The culmination of this series of notices and orders is that all uses of DBCP except for pineapples in Hawaii have been suspended and all uses are subject to pending cancellation.[1]

Prior to EPA actions, approximately 32.7 million pounds active ingredient of DBCP were applied annually to several crops including soybeans, almonds, vegetables, vineyards, peanuts, cotton, peaches, pineapple and citrus. DBCP uses accounted for about 9% of all insecticide/nematicide pesticides used annually in the United States.

Pending final outcome of cancellation proceedings, EPA has estimated the economic impact of EPA suspension and cancellation actions to be about $43 million. This figure does not include impacts in California (other than certain vegetable uses), which suspended all uses of DBCP in 1977. This estimate reflects revisions of certain impact estimates presented in the suspension hearing during 1979.

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[1] U.S. Department of Agriculture and U.S. Environmental Protection Agency. Economic Analysis of DBCP Cancellation on Selected Agricultural Crops. 1977.

Summary of Impacts of DBCP Suspension/Cancellation[1]

A. REGULATORY ACTIONS: Began September 1977 with notice to suspend and conditionally cancel some uses of DBCP. Actions continued through July 1979, when notice of intent to suspend all uses was issued.
October 1979: Suspension of all uses not suspended in Nov '77: cotton; soybeans; citrus; grapes; pineapples (except Hawaii); peaches; nectarines; plums; almonds; commercial okra; lima beans; smap beans, and southern peas; berries (black, blue, logan, dew, boysen, raspberry); strawberry nursery stock; apricots; cherries; figs; walnuts; bananas; tuff; ornamentals. also: Notice of intent to unconditionally cancel DBCP.

B. EXEMPTIONS: All uses except pineapple (HI) now suspended; all uses subject to cancellation notice.

C. EXTENT OF USE:

	Prior to EPA actions: lbs. a.i. appled/yr (1,000)
field crops:	18,272
fruit/nuts	9,732
vegetables:	3,392
other:	1,079
total suspended/ cancelled uses:	32,475
pineapple:	225
all uses:	32,700

D. SUBSTITUTES:

field crops:	D-D, EDB, dichloropropene, carbofuran fensulfothio, ethoprop, fenamiphos
fruits/nuts:	Preplant: D-D, EDB, dichloropropene Postplant: none for bearing trees, bushes or vines.

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[1] See: Arnold L. Aspelin, et al., EPA Pesticide Cancellations and Suspensions: A Survey of Economic Impacts, Office of Pesticide Programs, EPA, March 1980.

vegetables:	D-D, EDB, dichloropropene, Vorlex.
turf ornamentals:	Diazinon, fensulfothion, EDB, methyl bromide, dichloropropene.
home garden:	None postplant.
pineapple:	EDB.

E. ECONOMIC IMPACTS: Effectd due to EPA suspension/cancellations (millions):

field crops:	$23.09-23.48
fruits/nuts:	3.81- 4.21
vegetables:	14.09
other:	1.7
total suspended uses:	$42.69-43.48

8. 2,4,5-T and Silvex Suspension

On February 28, 1979, the forestry, right-of-way and pasture uses of both 2,4,5-T and silvex were suspended by EPA. At the same time several other uses of silvex were also suspended, viz., home and garden, commercial/ornamental turf, and aquatic weed control/ditch bank. The suspension will remain in effect until a final decision regarding cancellation is reached, approximately two years after the suspension.[1] Some uses were not suspended but the risks and benefits associated with these uses will also be evaluated during the cancellation hearings.

The economic impacts of suspending 2,4,5-T and silvex are generally limited to increased control costs, although some yield reductions may occur in the forestsry industry. The projected impact for all uses is approximately $90 million for the two-year suspension period. Forestry will realize estimated impacts of $46-$56 million during this two-year period. Rights-of-way impacts are estimated to range from $2.6 to $67.8 million for two years and average about $35 million, while pasture impacts are estimated at $5 million for two years.[1]

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[1] U.S. Environmental Protection Agency. Pesticide Industry Sales and Usage. 1979 Market Estimates. Economic Analysis Branch, BFSD, OPP. Washington, D.C., 1979.

Summary of Impacts of 2.4.5-T and Silvex Suspension[2]

A.	REGULATORY ACTION:	Suspension of forestry, right-of-way and pasture uses of both 2,4,5-T and silvex; additionally, suspension of home and garden, commercial/ornamental turf, and aquatic weed control/ditch bank uses of silvex, effective February 28, 1979 until a final decision regarding cancellation is reached.
B.	EXEMPTIONS:	Rice, range, and non-crop uses of 2.4.5-T and silvex; additionally, sugarcane and orchard uses of silvex; to be included in FIFRA section 6(b)(2) cancellation hearings.
C.	EXTENT OF USE:	
	Forestry:	Used in conifer production primarily in South and Pacific Coast regions; 0.23% commercial forest acres treated annually with 2,4,5-T; 2.6 million lbs. active ingredient 2,4,5-T/yr.; less than 1,000 lbs active ingredient silvex/yr. since 1977.
	Rights-of-way:	Eastern and Northwestern U.S. primarily; percent acres treated with 2,4,5-T: electric - 9.4%, railroad - 6.6%, pipeline - 4%, highway - 0.8%; minimal silvex usage - less than 2% of R-O-W firms; 3.8 million lbs. active ingredient 2,4,5-T/yr.; negligible quantity of silvex.
	Pasture:	Primarily South Central U.S.; 1% of total U.S. pasture acreage treated with 2,4,5-T, less treated with silvex; 500,000 lbs. active ingredient 2,4,5-T/yr.

1/ Arnold L. Aspelin, et al., *EPA Pesticide Cancellations and Suspensions: A Survey of Economic Impacts*, Office of Pesticide Programs, EPA, March 1980.

2/ Ibid.

Other silvex uses: Home and garden, commercial/ornamental turf, aquatic weed control/ditch bank; 2-3 million lbs. active ingredient silvex/yr.

Total suspended uses: Seven million lbs. active ingredient 2,4,5-T/yr.; 3 million lbs. active ingredient silvex/yr.

D. SUBSTITUTES: Generally available for rights-of-way, pasture, home and garden, commercial/ornamental turf, forestry site preparation and some aquatic uses at comparable or slightly higher cost; few available for forestry release and other aquatic uses.

E. ECONOMIC IMPACTS:

Forestry: Control cost and yield impact from 2,4,5-T suspension - \$10-\$17 million in first year, \$36-\$39 million in second year; negligible impacts from silvex suspension.

Rights-of-way: Increased treatment cost of \$1.3 million annually or, if treatment cycle is shortened from four to three years, increased cost of \$33.9 million/yr. (less than 0.1% of total operating expenditures);negligible imoact from silvex suspension.

Pasture: \$2-\$3 million annually from 2,4,5-T suspension (increased costs); unmeasured but small from silvex suspension.

Other silvex uses: No quantitative estimates; probably minor increase in control costs.

All suspended uses: Impact of \$13.3-\$75.9 million/yr. from 2,4,5-T suspension; negligible impacts from silvex suspension.

Impacts of Pesticide Cancellation on the Profitability and Related Aspects of the Pesticide Industry

Many industries make it hard to isolate pesticide manufacturers for statistical purposes. Under the Standard Industrial Classification system, chemicals and allied products are Major Group 28. However, industries which use chemicals in their processing can also be found in 14 other major SIC groups such as paper, petroleum, textiles, rubber, leather, metals, and photographic supplies.

Two major types of operations are involved in making pesticides: 1) manufacturing the chemicals used as active ingredients; and 2) formulating or combining these ingredients with inert materials. The manufacturers or producers are usually chemical, petroleum, or pharmaceutical companies. They synthesize the active ingredients in continuous processes at large, capital-intensive plants. There are estimated to be about 1,400 active ingredients, of which about 1,100 are in production.1/

The formulators are generally much smaller companies, although some are owned by producers and others work on contract to producing companies to market a product either under the producer's label or the formulator's own label. Farm cooperatives often formulate pesticides. Formulators use batch mixing and blending operations

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1/ Stanford Research Institute, New Innovative Pesticides: An Evaluation of Incentives and Disincentives for Commercial Development by Industry, prepared for Office of Pesticide Programs of the Environmental Protection Agency, Washington, D.C., March 1976.

to accomplish two purposes -- dilute the active ingredient so that it can be safely applied and put it into the most efficient form to reach its target. These products are then packaged for distribution. EPA estimates there are over 35,000 formulated products.[1/]

Pesticides account for a small fraction of the chemical industry. The value of pesticides as classified in SCI 2879 reached $3.4 billion in 1978 and increased to $3.8 billion in 1979.[2/] Statistics from the Industry Profile Survey of the National Agricultural Chemicals show sales close to $3.7 billion for 1979, over five times the figure for 1967 (see Table 57).

About 80 companies report to the International Trade Commission as producers of pesticides.[3/]

There are no official federal government estimates of profitability for pesticide industry sector. However, data on the individual chemical companies which are major pesticide manufacturers in the United States as shown in Tables 58 and 59 suggests that these firms have had good financial performance with net income as percent of sales averaging about 7.0 percent and net income as

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[1/] U.S. Environmental Protection Agency, Pesticide Industry Sales and Usage. 1979 Market Estimates, Economic Analysis Branch, BFSD, OPP, Washington, D.C., 1979.

[2/] U.S. Department of Commerce, Industrial Outlook 1980, G.P.O., Washington, D.C., 1979.

[3/] U.S. International Trade Commission, United States Production and Sales of Pesticides and Related Products, Washington, D.C., Annual Issues 1970 through 1975.

TABLE 57

DOMESTIC AND EXPORT SALES OF PESTICIDE MANUFACTURERS, PESTICIDES BY DOMESTIC UNITED STATES, 1967-1978
(in thousands of current dollars)

Year	Sales
1967	638,984
1968	690,969
1969	692,520
1970	722,516
1971	1,044,265
1972	1,153,868
1973	1,417,240
1974	1,956,308
1975	2,288,317
1976	2,557,758
1977	2,881,866
1978	3,369,765
1979	3,711,211

Includes sales of all respondents to the Industry Profile Survey of National Agricultural Chemicals Association.

Source: Ernst & Ernst, Industry Profile Survey, National Agricultural Chemicals Association (various years).

TABLE 58

NET INCOME AS PERCENT OF SALES FOR SELECTED CHEMICAL FIRMS WHICH ARE MAJOR PESTICIDE MANUFACTURERS IN THE UNITED STATES, 1976, 1977 AND 1978

Firm	Years		
	1976	1977	1978
DuPont	--	5.74	7.37
Proctor & Gamble	6.16	6.34	6.32
Union Carbide	6.95	5.47	5.01
Kodak	11.96	10.78	12.87
Dow	--	8.88	8.35
Monsanto	8.60	6.01	6.03
3M	9.65	10.38	12.08
W. R. Grace	3.73	3.59	3.95
Allied Chemical	4.46	4.63	3.68
FMC	3.85	5.17	4.77
PPG Industries	6.70	3.66	4.73
Cyanamid	6.48	5.78	5.68
Celanese	3.25	3.02	5.94
Pfizer	8.47	8.63	8.73
Merck	16.37	16.86	15.52
Hercules	6.69	3.41	5.31
Eli Lilly	14.90	14.42	14.98
Diamond Shamrock	--	10.59	7.81
Olin	5.27	5.30	4.02
Abbott Lab.	8.53	9.47	10.29
Ethyl Corp.	6.08	6.09	5.81
Upjohn	7.56	8.07	9.74
Stauffer	10.27	9.41	9.49
Rohm & Haas	--	3.45	4.41
Asarco	3.83	(-2.82)	4.21
Westwaco	6.15	6.19	5.79
GAF Corp	00	(-5.11)	3.21
Pennwalt Corp.	4.49	5.00	4.88
Akzona	0.77	0.93	2.40
Reichald Chem	2.75	2.03	1.60
NALCo	11.64	11.55	8.23
Great Lakes Chem.	15.78	16.31	15.18

TABLE 59

NET INCOME AS PERCENT OF STOCKHOLDERS EQUITY FOR SELECTED CHEMICAL FIRMS WHICH ARE MAJOR PESTICIDE MANUFACTURERS IN THE UNITED STATES, 1976, 1977 AND 1978

	Year		
Firm	1976	1977	1978
DuPont	--	12.63	16.53
Proctor & Gamble	17.01	17.58	17.55
Union Carbide	14.44	11.30	10.84
Kodak	16.16	14.86	18.57
Dow	--	17.88	16.95
Monsanto	17.31	11.93	12.21
3M	16.57	18.25	21.72
W. R. Grace	11.69	11.57	12.16
Allied Chemical	10.58	11.30	9.45
FMC	9.24	12.68	13.43
PPG Industries	14.85	8.63	11.41
Cyanamid	12.33	11.93	12.43
Celanese	8.67	8.45	16.38
Pfizer	--	15.62	16.[illegible]1
Merck	21.18	22.75	21.13
Hercules	14.39	7.65	12.65
Eli Lilly	18.63	18.26	20.05
Diamond Shamrock	--	20.45	14.32
Olin	12.21	11.96	9.08
Abbott Lab.	16.09	17.75	19.21
Ethyl Corp.	14.52	14.82	14.15
Upjohn	15.81	16.67	20.23
Stauffer	18.93	17.14	16.55
Rohm & Haas	--	7.44	9.92
Asarco	4.94	(-3.65)	5.30
Westwaco	13.43	13.24	12.87
GAF Corp.	0.01	(-14.24)	9.71
Pennwalt Corp.	--	13.54	13.40
Akzona	1.83	2.51	6.77
Reichald Chem.	10.78	7.04	6.30
NALCo	23.77	24.06	17.66
Great Lakes Chem.	25.43	24.49	22.97
Terra Chemicals	18.81	12.02	2.04

Source: SEC 10-K Reports.

percent of stockholders equity about 14.0 percent. The average net income as percent of stockholders equity for all manufacturing is about 15.9 percent.

Looking at the pesticide segment of the chemical industry, net sales have increased from about $800 million (in constant 1972 dollars) in 1970 to slightly less than $2.06 billion in 1977, an increase of 157 percent. This rate of growth is larger than for many chemical subsectors and larger than that for the chemical industry as a whole.[1]

This significant increase, however, is not evenly distributed among the pesticide products groups (shown in Table 60). As the data in this table show, the market can be subdivided essentially into six major categories with herbicides the largest, and plant growth regulators the smallest.

The relative position of these groups has not remained constant. During the sixties and early seventies, the key growth area was herbicides, with an annual growth rate in the 1970-1978 period of about 12 percent. According to industry experts, this rapid growth of herbicides was due to the increasing cost of agricultural labor and because a substantial number of new herbicides were introduced in the market during the late 1950's and mid-1960's. While the introduction of new herbicides has slowed down somewhat in recent years, new products continue to be introduced and future growth prospects for herbicides appear to be good.[2]

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[1] U.S. Environmental Protection Agency, Pesticide Industry Sales and Usage. 1979 Market Estimates, Economic Analysis Branch, BFSD, OPP, Washington, D.C., 1979.

[2] National Academy of Sciences, "Volume 1 Contemporary Pest Control Practices and Prospects: The Report of the Executive Committee", Pest Control: An Assessment of Present and Alternative Technologies, Washington, D.C., 1975.

TABLE 60

DOMESTIC AND EXPORT SALES OF PESTICIDES BY MAJOR TYPE BY DOMESTIC PESTICIDE MANUFACTURERS, UNITED STATES, 1967-1978

(in thousands of current dollars)

Year	Sales						Total
	Herbicides	Insecticides	Fungicides	Plant Growth Regulators	Nematicides	Miscellaneous	
1967	269,563	249,308	42,157	NA	NA	70,286	638,984
1968	289,725	275,794	42,835	NA	NA	82,615	690,969
1969	295,684	280,720	44,995	NA	NA	71,125	692,520
1970	331,549	279,651	46,582	NA	NA	64,734	722,516
1971	587,768	333,985	46,615	NA	NA	76,897	1,044,265
1972	653,551	368,356	51,558	NA	NA	80,403	1,153,868
1973	804,495	467,885	57,998	NA	NA	86,862	1,417,240
1974	1,025,834	586,309	152,069	15,002	35,029	29,763	1,844,006
1975	1,402,180	688,904	152,545	22,285	56,551	34,988	2,357.453
1976	1,441,079	737,926	166,021	22,453	60,814	43,071	2,471,364
1977	1,605,059	934,524	197,886	23,414	68,832	38,933	2,881,866
1978	1,894,171	1,073,244	229,762	30,879	74,282	67,427	3,369,765

Includes sales of all respondents to the Industry Profile Survey of National Agricultural Chemicals Association.

Source: Ernst & Ernst, Industry Profile Survey National Agricultural Chemicals Association (various years).

Since the mid-1970's, the growth of the insecticide market has marginally exceeded that of herbicides; annual average growth rate of insecticide sales in the 1970-1978 period was about 13 percent. Industry analysts expect that new insecticides will be developed because of adverse toxicological findings on existing products and the resistance of pests to insecticides. Sales of various insecticide products are expected to increase because of the development of new insecticides, and because reduced prices resulting from the lapse of existing patents on major insecticide products will stimulate increased competition.

The annual growth rate of fungicide sales in the 1970-1978 period was the smallest among all pesticide groups at only 8 percent. Significant market development of plant growth regulators has taken place during the last five years. In the 1970-1978 period, the annual growth rate for these products was 11 percent; industry anticipates considerable continued growth in this pesticide subsector. The growth rate for nematocides in the 1970-1978 period has been approximately 10 percent per annum, and as in the case of plant growth regulators, this growth is expected to increase in the future.

In summary, the overall annual growth rate for the pesticide industry in the 1970-1978 period has been about 11 percent. Current trends and industry experts indicate that this rate will continue in the future and even increase. Uniroyal Chemical Company, for example plans to register five new pesticides in the early eighties. A company official says "The insecticide market is a very viable market. There is a need to replace products that have been withdrawn from the market for various reasons or where resistance problems have developed." The company expects its sales in agricultural chemicals to double in four years.[1] Carl Gerstacker of Dow predicts that agricultural chemicals will be a major growth field in his look at the chemical industry in the 1980's.[2]

In summary, the available data clearly indicate that pesticide cancellation by the Environmental Protection Agency has had apparently no adverse effects on the chemical industry's growth, increase in sales and profitability.

The fundamental reason for this lies in the fact that most, if not all, specific pesticides have not one, but several, substitutes which can be readily used if a certain pesticide is cancelled or otherwise regulated. Another reason for the minimum impact of pesticide cancellation is the continuous research and development effort by pesticide manufacturers which results in a continuous and steady introduction of new pesticides in the market.

Impacts of Pesticide Cancellation on Substitute Development

As discussed in the previous section, the pesticide industry is comprised of a large number of multi-product firms with significantly large investments in capital and with an equally large workforce.

1/ "Ag Chem Research is on the Move at Uniroyal", Farm Chemicals, November 1978, p. 56.

2/ Chemical and Engineering News, November 26, 1979.

Clearly, the cancellation of the pesticides described above must have an impact on the development of substitutes. However, it is not possible to exactly determine the specific research and development and related activities which are associated with each pesticide cancellation. This is the case because at any one time period, each and every pesticide manufacturer has already developed a number of substitute pesticides which can be used for a specific purpose, although clearly there always exists a specific pesticide which produces optimum results as well as is most cost effective for the user.

Furthermore, at any one time period, each and every pesticide manufacturer is undertaking simultaneous research and development and related activities for several new pesticides.

Thus, to isolate specific responses by the pesticide industry to specific pesticide cancellations is not possible. Conversely, it is possible to analyze the overall research and development activities and trends in innovation by the pesticide industry during the period when the pesticide cancellation took place, i.e., 1971 to 1979.[1]

Such an analysis, while not indicating exactly the impact of the pesticide cancellation discussed above, should nevertheless provide some measure of information on the pesticide industry's response to pesticide cancellation in terms of research and development activities and innovation directed towards development of substitutes for the cancelled pesticides.

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[1] Note, however, that most of the available information pertains to agricultural chemicals rather than to pesticides.

Looking at agricultural chemicals (there are no data for pesticide industry) the Science Indicators 1978[1] shows a 24 percent increase for applied research and development expenditures (expressed in constant dollars) between 1971 and 1977. The number of research and development personnel in companies participating in an NACA survey more than doubled between 1967 and 1978 (Table 61). Research and development as a percentage of pesticide sales declined between 1970 and 1978 from a high of 9.7 to 8 percent, according to NACA figures.

The Chemical Abstracts Service has, since 1965, assigned CAS numbers to chemical formulas reports in the world chemical literature. They assigned about 278,000 numbers in 1972 and 360,000 in 1979. About a fourth of these are from the U.S., according to CAS. CAS has about a three-month backlog. The total number of chemicals reported is about 4.8 million.

The best measure available for the number of new chemicals developed for use as pesticides is probably the number of new chemical applications for registration. This number for new chemicals is not now available from EPA, although the total number of applications for all new registrations for new chemicals and formulations is known. This latter figure ranged between four and five thousand a year between 1950 and 1968. Since then, it has varied from about 1500 to 3000 per year.

1/ National Science Foundation, Science Indicators 1980, Washington, D.C., 1981.

2/ Wechsler, Alfred E., Joan E. Harrison and John Neymeyer, Evaluation of the Possible Impact of Pesticide Legislation on Research and Development Activities of Pesticide Manufacturers, prepared for Office of Pesticide Programs of the U.S. Environmental Protection Agency, Washington, D.C., February 1977.

TABLE 61

PERSONNEL IN PESTICIDE RESEARCH AND DEVELOPMENT 1/

Composite Analysis of All Reporting Companies

United States and International	Number of Employees											
	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
Level of Education:												
Doctoral Degree	584	619	689	739	605	652	713	930	1070	1161	1220	1291
Masters Degree	224	243	275	272	346	383	412	502	539	602	658	679
Bachelor's Degree	565	578	623	628	615	669	726	863	798	875	957	1008
Other training and nontechnical	865*	909*	911*	913*	938	957	1015	1896	2014	2130	2109	2110
Total	2238	2349	2498	2547	2504	2661	2836	4191	4421	4768	4944	5088

1/Personnel whose efforts are directed toward pesticide R & D

* Figures do not include International personnal to avoid disclosure of individual company data

Source: Various NACA Industry Profile Studies

The number of actual new chemical registrations is probably at least as much a measure of EPA efficiency as company innovation. The number has varied considerably since 1967 with lows of 3 and 4 and a high of 33. After a sharp decline between 1975 and 1977, it is now increasing once more. These figures, of course, are not helpful in measuring whether better and/or safer pesticides are being developed or whether the new pesticides satisfy needs for which there are no alternatives available.

Researchers have generally found a correlation between the annual patenting rate and the degree of technological change occurring in an industry.

Science Indicators 1978[1/] includes a comparison of patents granted to U.S. inventors in 1967 and 1977. The data shows a 10 percent decline in patents granted to U.S. inventors in the chemical and allied products field as a whole. When these data are disaggregated, however, they show a 21 percent decline in industrial chemicals and a 23 percent decline for plastics. At the same time, they show a 79 percent increase for agricultural chemicals, the largest increase for all product fields.

Data show patents granted to U.S. inventors for agricultural chemicals increasing steadily from 480 in 1963 to 1227 in 1977 with a few fluctuations probably due to the Patent Office's procedures rather than the number of applications submitted. When classified by date of application rather than by the date granted, the number of agricultural chemical patents has also increased steadily.

[1/] National Science Foundation, Science Indicators 1980, Washington, D.C., 1981

Science Indicators 1976[1] includes a study of 310 major innovations by industry. The chemical industry (there is no information on pesticide sector) is credited with 15 percent of all major innovations between 1953 and 1973. As the above information suggests, the pesticide industry, during the period when a number of pesticides were cancelled by the government, increased research and development expenditures and increased a number of other measures related to innovation.

Whether or not these increases can be directly associated with pesticide cancellation can not be stated with certainty; nevertheless the pesticide industry undertook measures which resulted in the developments of new pesticides.

Impact of Pesticide Cancellation on Industry Structure

As already described, the pesticide industry is highly concentrated. Only about 50 firms in the U.S. conduct research leading to new pesticide products. Twenty-five firms that are among the top 50 chemical companies (as measured by chemical sales) accounted for 54 percent of the new pesticides registered with EPA between 1972 and 1979.

1/ National Science Foundation, Science Indicators 1976, Washington, D.C., 1977.

Individuals familiar with the industry claim that the degree of concentration has increased steadily over the past 30 years. Comparison with other segments of the chemical industry lends support to the concentrating influence of pesticide regulations. In most other segments of the industry small firms play an important role in developing new chemicals. This is not true for pesticides.

Pesticide cancellation and other government regulations such as TSCA clearly have the potential for having the same concentrating effect. The one published study of TSCA impact on the industry[1/] examined the effect on innovation of the costs of filling out the premanufacture modification form (PMN) initially proposed by EPA. The cost of any necessary testing for new chemicals was not included. The study found that 50 percent of chemicals currently being introduced for commercial sales would not be introduced if the TSCA notification costs were $10,000 per chemical. At a unit modification cost of $40,000, 90 percent of the chemicals would not be introduced.

There are three mechanisms related to government regulations which impact on small firms: 1) by imposing testing and other costs which must be paid before a chemical can be marketed, and by extending the time that elapses between development of a chemical

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[1/] Arthur D. Little, Impact of TSCA on the Pesticide Industry (draft), Boston, Massachusetts, 1979.

and its marketing, the law may require an initial investment that exceeds the capital that can be generated by a small firm; 2) the added costs of entry into a market increase the size of the market necessary for a satisfactory return on investment. This may make many of the traditional markets of the smaller firms uneconomical. Also, larger markets are likely to increase the competitive advantage of the economies of scale possessed by the larger firms; and 3) the time delay and added costs may remove the flexibility that is one of the major competitive advantages of the smaller firms. The size of market problem also obviously limits flexibility.

The extent to which greater concentration has or will inhibit innovation is a matter of dispute.

FIFRA, another government regulation which impacts on pesticide manufacture, does not seem to have discouraged large foreign firms from entering the U.S. Market. CIBA-GEIGY, Bayer, and other international giants account for a significant proportion (at least 15%) of U.S. pesticide registrations.

Pesticides manufactured in the U.S. can be exported to other countries, provided that they carry appropriate warning labels, even if they have never been registered or their registration has been cancelled or suspended. Thus, FIFRA does not inhibit U.S. exports, and the export market constitutes a major portion of the business of many U.S. firms.1/

1/ Note however that this "export" market essentially means production of pesticides abroad by U.S.-owned firms. Note also that there are no data as to the magnitude of this production.

Similarly, there is no evidence nor any apparent reason why FIFRA should encourage U.S. firms to conduct either pesticide research or manufacturing outside the U.S. Tax laws and the Occupational Safety and Health Act may have this effect. Also, it is reportedly easier to obtain approval to sell pesticides in certain countries if the research and/or the manufacturing is conducted in that country. But these factors are not influenced by FIFRA.

The effect that TSCA will have on international trade is unclear at the present time. Europeans have been concerned that the law would be a major impediment to entering U.S. chemical markets. This concern has accelerated legislative action in Europe, and in June of 1979, the European Economic Community (EEC) unanimously approved the so-called Sixth Amendment Directive (EEC, Council Directive of 18 September, 1979, amending for the sixth time Directive 67/548/EEC). The directive gives each of the EEC member nations two years to pass national legislation requiring notification and testing of new chemicals. A major motive for approving the directive at this time was to give the EEC a bargaining position to effect changes in TSCA.

The Sixth Amendment Directive differs from TSCA in several important respects. Unlike TSCA, its new chemical notification provisions excludes chemicals manufactured in small volumes, polymers, and chemicals manufactured for use only within the manufacturing firm. Unlike TSCA, it specifically delineates the tests that must be performed on new chemicals. And, most notably, it gives each firm a proprietary right for ten years to test data developed by the firm. Whether and to what extent these differences between TSCA and the EEC directive are reconciled will determine the effects of TSCA and the European actions on international trade patterns.

In summary, cancellation of certain pesticides by the Environmental Protection Agency, perhaps the most explicit end-product regulation by the federal government, has resulted in negligible impacts on the users of the pesticides, the general public and the pesticide manufacturing industry. The principal reason for this lies in the fact that most pesticides have one or several substitutes. There are several reasons for this. The principal ones are as follows:

- profit motive by a firm to develop better substitute for existing pesticides;[1]
- development of both broader and narrower spectrums of new pesticides as substitutes for existing products;[2]
- development of new pesticides in order to overcome resistance by target populations[3]; and
- new knowledge of genetic and biological factors leads to new pesticide development.[4]

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[1] National Academy of Sciences, Pest Control: An Assessment of Alternative Technologies, Washington, D.C. 1975.

[2] P. G. Georghion, "The Management of Insecticide Resistance", paper presented on Pesticide Resistance International Congress on Plant Protection, Washington, D.C. August 5-11, 1979.

[3] See: C. J. Shapiro, "Future Sources of Organic Raw Materials," Science, October 26, 1978.

[4] See: Georgia Institute of Technology, Technological Innovation: A Critical Review of Current Knowledge, prepared for N.S.F. 1975.

Critical Analysis and Rankings of Federal Government Policies Which Resulted in End-Product Substitution

As presented in the previous sections of this report Federal Government has essentially attempted a single type of policy which has resulted in end-product substitution -- that of outright prohibition of certain products. This section presents critical analyses of this policy in light of current regulations e.g. Executive Order #12291. Government regulations which required substitution of various products containing PCB's with other end-products is one example of end-product substitution resulting from public health considerations. Regulations leading to substitution of lead used as pigments in oil-based paints is another such example.

Another example of such public health related policies by Government is the pending regulation to suspend the use of DEHP's, a family of compounds[1] used in various applications with PVC resins as plasticifers.[2]

In almost all cases where the Federal Government has issued regulations which have resulted in end-product substitution such regulations have been enacted in order to protect the public from health hazards. The regulations directed towards substitution of certain pesticides also discussed in the previous sections is, perhaps, the most visable government regulation which has led to the end-product substitution, because of health considerations.

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[1] DEHP's represent a generic name for a series of phthalic anhydride esters.

[2] A.D. Little, Inc., "Risk assessments of priority polluntants: Phthalate estera." Office of Water Planning and Standards. Washington, D.C., U.S. Environmental Protection Agency. EPA Contract 68-01-3857, 1979.

Another principal reason for Federal Government regulations leading to end-product substitution is occupational health and safety considerations. Regulations directed towards reduction and/or cancellation of the use of benzidine congener dyes, chlorinated dioxins, chlorinated solvents (i.e. trichloroethylene, perchloroethylene, methylchloroform, etc.), beryllium, acrylonitride and others, all have been enacted principally because of occupational exposure of these compounds to the workers. 1/ Federal Government has enacted regulations which result in the end-product substitution for very few other reasons other than health and safety considerations.

One principal exception to this is in the area of energy conservation when Federal Government regulations have led to end-product substitution which results in energy savings. Substitution of various components in motor vehicles in order to achieve weight reduction of a motor vehicle and therefore reduce

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1/ On this see: Interagency Regulatory Liaison Group, Hazardous Substances, 1980 and National Institute for Occupational Safety and Health, U.S. Department of Health and Human Services, Guide to Chemical Hazards, Government Printing Office, Washington, D.C., 1980.

gasoline consumption represents an excellent example of the energy conservation regulations and the resulting end-product substitution. [1] The important conclusion, which needs to be established and which will impact on the critical analysis of government policies which have resulted in end-product substitution, is that most of the government policies and/or regulations which have resulted in end-product substitution have been enacted to protect public health and safety.

As already noted regulations pertaining to energy conservation which have resulted in end-product substitution are the exception to the conclusion presented above, and there may be other non-public health and safety related government policies which result in end-product substitution. However, most of the government policies which have caused end-product substitution have been enacted in order to protect society's health and safety. With this in mind we now turn to critical analyses of these Federal Government public policies.

1/ Note however, that these end-product substitutions may or may not reduce hazardous waste generation and emissions.

Public policy, as a rule, is developed and administered through the application of a prescribed framework of criteria. As regulated activities increase in technical complexity and in potential impact on society, the need emerges for an agree-upon set of principles to support analysis and development of regulatory positions.

The methodology of benefit-cost anaysis has been accepted by the Federal Government, providing a basis upon which to establish criteria for evaluating decision processes for public health and safety management. 1/ Note however, that the benefit-cost anaylsis referred to here is broad in context and includes a mixture of economic as well as political issues. Federal courts have systematically upheld such decision-making processes as for example, in the case of Crowther vs. Seaborg, a case involving the Atomic Energy Commission. The court recognized that the standard-setting process mandates a mix of scientifc and political judgments, and concluded that:

> "The setting of a standard at a given level requires the weighting of these risks and benefits to be derived therefrom. The weighing requires a value judgment as well as a measuring and thus the standards are not scientific numbers below which no danger exists. 2/

An excellent example of such criteria can be cited: Appendix I, entitled Numerical Guidelines for Design Objectives

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1/ 321 F. Supp. at 1231.

2/ As a matter of fact, benefit-cost analysis is also the method by which energy conservation policies are measured. See: Department of Energy; Benefit-Cost Analysis of Selected Energy Conservation Measures, (draft) 1981.

and Limiting Conditions for Operation to Meet the Criterion "As Low as Practicable" for Radioactive Material in Light-Water-Cooled Nuclear Power Reactor Effluents, adopted on April 30, 1975, by the AEC's successor, the Nuclear Regulatory Commission. *Appendix I* has become the fundamental source of information and guidance on NRC's analytical approaches rulemaking and other regulatory activities applicable to radiation. Note that the cited criterion is relatively broad in application, and, further, that it comprises a mix of scientific and political judgments. Further evidence of the broad application of judgment that can be used in public policy decisions involving potential societal risks can be seen from rulings by the Nuclear Regulatory Commission.

NRC has determined that when public policy analysis is used in reactor site selection under NEPA, the site ultimately chosen need not be the best one. Any site which the analysis indicates is favorable may be selected, as long as it can be shown that no "obviously superior site" exists. [1/] This NRC determination is in accord with its view that, under NEAP, environmental or health advantages do not automatically take precedence over all other matters, and that the results of any analysis are inherently too uncertain to be accorded any greater weight in the licensing decision.

This mixture of the scientific with political, social, and even moral considerations is a key requirement in developing

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[1/] *In the matter of Public Service Co. of N.H., et. al.*; 5 NRC 503 (1977), pp. 527-530; and discussed in the NRC Case Study in the Appendix to this report.

public policy to deal with policies and regulations resulting in end-product substitution.

Prior to examining government policies which have resulted in end-product substitution, it is useful to present and discuss a list of broad criteria for evaluating such public policies. Several sets of such criteria have been developed, however, for the most part, they address very specific societal risks (i.e., nuclear wastes). 1/ Our literature search failed to locate a broad range criteria for evaluating public policies related to end-product substitution.

However, most if not all of the critical evaluations of Federal Government policies and the use of benefit-cost analyses to guide such policies suggest that at the minimum, benefit-cost analyses should contain adequate representation of parties who bear costs and who derive benefits and careful and valid quantification of benefits and costs.

The following two sections present theoretical discussion of these issues followed by application of these to the selected case studies and the government's policies of suspension of certain pesticides presented above.

1/ See for example: Davies, J.C. ed., "Decision-Making for Regulating Chemicals in the Environment," National Academy of Sciences, Washington, D.C., 1975; Greenfield, M.A. and Starr, Chauncey, "Public Health Risks of Thermal Power Plants," Nuclear Safety, Vol. 14, July-August 1973; Conley, B.C., "The Value of Human Life in the Demand for Safety." Research Report, Center for Public Economics, California State University, San Diego, 1973; and Hirshleifer, J., Bergstrom, T., and Rappaport, E., "Applying Cost-Benefit Concepts to Projects which Alter Human Mortality," University of California, Los Angeles, Department of Engineering, November, 1974.

Adequate Representation of Parties Who Bear Risks (and Costs); Who Derive Benefits

Whenever the public is directly and immediately exposed to risks as a result of public policies, public representation must be ensured in the development of those policies.

It is important to distinguish "society as a whole" from "the rest of society apart from a particular group." If a program or measure is definitely to the benefit of a special group within society, then it is perfectly proper to ask whether the rest of society shall accept this program or measure though the entire benefit from it accrues only to that group, only to that particular part of society.

To be sure, the one group is part of society. But society has a right to ascertain how much of the total benefit goes to a particular group and how much goes to the rest. For activities involving risks from hazardous compounds, representation of the risk-bearers becomes even more crucial.

The question can be asked, however, to what extent should the government go beyond assuring representation of various population groups by determining specially impacted population sectors on the basis of age (e.g., children), location (at different distances from facility site), or other criteria? Constitutional considerations of equal protection are raised when one considers the representation of effects of regulatory decisions.

The issues of adequate representation are also embodied in Rawls' contract theory to provide an account of justice that is superior to utilitarianism and a more adequate basis for a democratic society. [1] Adequate representation of all public sectors depends on adequate funding. The technical complexity of many societal risks requires expertise in addressing the issues and representing the risk-bearing populations. Because most public action groups are poorly financed, it is incumbent on the government to arrange some means of compensating those parties who successfully intervene on the side of the risk-bearers. Precedent for such compensation can be found in the legal process. In class action suits, successful attorneys for plaintiffs can expect to receive fees as well as reimbursement for expert witnesses and related costs. It can be argued that such compensation is justified in other types of government proceedings as well. Protection of the public interest cannot be left to the regulatory agencies, because their interests and statutory missions may be far narrower than the interests of the general public.

It is equally important to consider the benefits derived from an action. Even when substantial costs can be demonstrated, benefits should be examined for they may far outweigh the costs in some cases.

"Efficiency and effectiveness of government and decision-making beg the question 'for whom?' and 'in whose terms?' Social, economic, and political reality is not the same for all sections of the population. Within the government services some gain and some lose in every policy and programme; this is a political rather than managerial question."[1] Thus, without public participation, economic analysis of low-probability high-consequence risks may have little relevance to society's goals.

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[1] John Rawls, "Concepts of Distributional Equity: Some Reasons for the Maximum Criterion," American Economic Review, Vol. 64, No. 2, pp. 141-146.

Arnstein defines public participation as "...the redistribution of power that enables the have-not citizens presently excluded from the political and economic processes, to be deliberately included in the future."[2] Arnstein has developed a typology of eight levels of participation, arranged in a ladder pattern with each rung corresponding to the extent of citizens' power in determining the end product.

The lower levels represent systems contrived to give only the appearance of genuine participation. Above that level, "tokenism" allows opinon to be voiced but reserves decision-making for the power-holders. The upper levels include partnerships allowing negotiation and, finally, complete citizen control in which the public retains the majority share of the decision-making power.

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[1] J. Benington and P. Skelton, "Public Participation in Decision-Making by Governments" in Government and Programme Budgeting: Seven Papers with Commentaries, The Chartered Institute of Public Finance and Accountancy, London, 1973.

[2] S.L. Arnstein, "A Ladder of Citizens Participation," Journal of American Institute of Planners, July 1969, p. 216.

Generation, emission and disposal of some hazardous wastes create long-range effects that may transcend generations. Our regulatory policy proceedings and our legal system are not designed to address issues of distribution over time involving the allocation of costs and benefits for future generations. We have neither established the legally protected interests of future generations, nor designated representatives of future interests. Our laws and values prefer current benefits over future ones. In addition, most public policy analysis reflects this limited view.

However, in evaluating the acceptability of proposed risk associated activities, one must not be trapped by the economic status quo. Our economy is a complex system of dependent parts. The economic system is also dynamic. Its major characteristics have changed in the recent decades: changes in the mix of environmental and econmic well-being have occurred and will continue to do so, as well as changes in the mix of capital and labor, goods and services, and many other basic relationships in the economy. Consumer expectations are also adaptable.

For these reasons, any benefit-cost analysis which fails to look at the long-term adaptability of the economy to major regulation, and which instead concentrates on short-term effects, is seriously biased against health and environmental protection measures. Clearly, one goal of the health and environmental laws is to lead our economic growth in directions that are safer for human and natural systems. Any regulation of serious risks that accepts the economic status quo as something that may not be altered falls short of accomplishing the goals of these laws.

Every public policy decision related to societal risk results in costs that will be distributed in some pattern across different population sectors.

The major aspect of risk related policy analysis not adequately covered in the analysis of costs and benefits is the question of how the costs and benefits are distributed. In this sense regulatory decisions are essentially political decisions. Four dimensions of the distribution of costs and benefits are particularly important: geographical distribution, distribution among social classes, distribution over time, and distribution among levels of government.

Geographical distribution. The geographical aspects of how costs and benefits of regulatory decisions are distributed is, if anything, likely to given excessive importance in the U.S. The reasons for this are apparent to anyone who knows how the U.S. Congress is elected. The composition of the Congress and the decentralized basis of the political parties assure that decision makers will give adequate attention to the impact of decisions on particular communities. The role of the type of analysis outlined earlier in this report is, in part, to provide some perspective and counterbalance to the pressures of the political system.

Distribution among classes. There are two aspects of distribution among classes. The first involves the effects of a decision on different income classes. This has been a major question in some policy areas.

The second aspect involves distribution among workers, consumers, and the general public. The problems presented by this aspect are as much legal as distributive. Each of these three segments of the public are covered by different laws. Thus the regulatory alternatives considered and the information received will have to be viewed in the light of which segments of the community are at risk. There may also be equity problems if the stringency of interpretation or effectiveness of enforcement differs among the various acts.

Benefit distribution tends to be even more complex and involve more widespread population groups making it more difficult to identify than that of costs/risks. Careful identification of the segments of population affected by a policy decision is mandatory, because only then can the public be adequately represented and their rights and interests safeguarded. Rarely is consideration extended to specially impacted population sectors on the basis of age (e.g., childre, the elderly) or location (distances from site).

It is of some interest to note that the issues related to distribution of benefits and costs have received closer attention as government intervention in the daily life of society via various public policies increases. An excellent   article summarizes the consensus among public policy makers on this issue:

> "Likewise, it might be that an acceptable principle of social ordering (an acceptable "social welfare function") would reject Rawls' strict formulation

> of the lexical difference principle,[1] (which says, intuitively, that no person is ever to be benefitted at the expense of any worse-off person) while still refusing to accept the utilitarian premise that any reduction in the wefare of an individual person can be justified by a large enough total gain for others. Instead one might believe, for example, that certain gains in equality (perhaps as reflecting some measure of the gross dispersion of certain fundamental goods) or even in cultural excellence (perhaps as reflected in the heritage left to succeeding generations), but only such gains, can justify some (but not all) kinds of degrees of reductions in the welfare of even the least well-off members of a society."[2]

Care in Quantifying Conceptually or Empirically Difficult Risks (and Costs); Benefits

Cost/Benefit analysis is valid only when the costs and benefits being weighed can be assigned a quantitative value by some socially-acceptable process. In the case of many activities this is a very difficult undertaking.

For example, let us consider the value of human life because of the potential impact of hazardous waste on human health and therefore, life. Although the notion that human life is an absolute value that should override any consideration of other values may be ethically appealing, it is not very useful because there are other things that people value besides health and safety, and there are not sufficient resources to both maximize these values and achieve the other things that society values.

1/ A lexical ordering is one that effectively ranks alternatives with regard to one attribute at a time. See: John S. Chipman "The Foundations of Utility," Econometrica 28 (1960), p. 193.

2/ Laurence H. Tribe, "Policy Science: Analysis of Ideology," Philosophy and Public Affairs, Vol. 2, No. 1, (1972), pp. 66-110.

Unfortunately, a review of most of the important studies and calculations of the value of human life[1] indicates no consensus.

The Nuclear Regulatory Commission has adopted a value of $1,000 per man rems, which when multiplied by the number of rems capable of producing different types of deaths, provides dollar values for human life. The Environmental Protection Agency's Office of Radiation Programs, also dealing with the health effects of radiation, has chosen a value of $500,000 per life, or more precisely, has chosen to establish its environmental radiation standards as levels which will not cost more to implement than $500,000 for each life to be saved.[2] The Consumer Product Safety Commission has used values ranging from $200,000 to $2,000,000 per life in different analyses.

In their studies of flammable standards the National Bureau of Standards has used a value of $300,000 per life. [3]

1/ Dorothy P. Rice and B.S. Cooper, "The Economic Value of Human Life," American Journal of Public Health, Vol. 57, No. 11, (November 1967), pp. 1954-1966.

2/ Environmental Protection Agency, Office of Radiation Programs, Environmental Radiation Protection Requirements from Normal Operations of Activities in the Uranium Fuel Cycle, Final Environmental statement, U.S.E.P.A., (November 1, 1976), more precisely has established radiation standards at levels which will not cost more to implement than $500,000 for each life to be saved.

3/ Preliminary Report on Evaluating Alternatives for Reducing Upholstered Furniture Fire Losses, U.S. National Bureau of Standards, NBSIR-77-1381 (November 1977).

Other human life values used by federal government agencies can be readily added to this list, but the above should suffice to indicate the wide variations in these values. Such wide differences in valuation can lead to contrasting conclusions. How does one select the best valuation? Should it be based on insurance statistics, jury awards, "willingness to pay" findings, or potential lifetime earnings? [1] Finally, one must ask, should we use monetary values in place of such attributes as human life?

However, in the case of programs related to hazardous waste abatement, such estimates play a major role because the very term "hazardous wastes" connotes possible loss of life and injury to health. It is therefore of some importance that an attempt to estimate the costs of death and illness that may occur as a result of hazardous waste emissions be undertaken. Fortunately, some recent analytical developments may provide methodologies for estimation of such costs. In addition to the inherent problems of estimating costs of life and health, other cost/benefit measures are difficult to estimate.

Robert Dorfman's essay on "Methods of Policy Analysis" written for the National Research Council (National Research

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[1] E.J. Mishan, for example, states: "None of the existing methods of evaluating loss or saving life, or assessments on increase or accidents resulting from investment projects, is satisfactory for a number of reasons." E.J. Mishan, "Evaluation of Life and Limb: A Theoretical Approach" in A.C. Harberger et. al. (editors), Benefit Cost Analyses 1971, Chicago, Illinois, 1972, p. 103.

See also, J. Rothenberg, The Measurement of Social Welfare, Englewood, New Jersey, 1961.

Council, Decision Making in the Environmental Protection Agency, Vol. IIb, "Selected Working Papers," pp. 82-91) provides excellent examples of these. Dorfman's illustrative format of a quantitative policy analysis includes several monetary (i.e., expressed in dollar terms) and non-monetary elements.[1] The latter include "reduced days of restricted activity, increased recreational use, and reduced days of ardor." However, when he turns to the question of making a decision among several alternatives, he begins by directing the reader to "assume that all important non-monetary benefits associated with the different alternatives can be expressed in a common unit such as lives saved." If such an assumption can be made, then a number of useful analyses can be performed as Dorfman illustrates.

> If the population density, including weighted transient population, projected at the time of initial operation of a nuclear power station exceeds 500 persons per square mile averaged over any radial distance out to 30 miles, or the projected population density over the lifetime of the facility exceeds 1,000 persons per square mile averaged over any radial distance out to 30 miles, special attention should be given to the consideration of alternative sites with the lower population densities.[2]

1/ For excellent discussion of issues related to incommensurables see: Roland N. McKean, "Cost-Benefit Analysis and British Defense Expenditure," Scottish Journal of Political Economy, February 1963, pp. 17-35.

2/ Regulatory Guide 4.7, "General Site Suitability Criteria for Nuclear Power Stations," NRC p. 4.7-16.

The problems related to the quantification of benefits and costs are well recognized by those working in risk analyses as well as public officials. The Senate Committee report discussing the cost of Clean Water 1972 Amendments should be considered in establishing effluent limitations, but it recognizes that "no mathematical balance can be achieved in considering relative costs and benefits no would any precise formula be desirable.[1]

In summary it is worth repeating here the conclusions reached by McKean:

> "What we really face...is an amorphous and shifting preference function emerging (implicitly) from the political process, and a complex economy dominated by uncertainty. I have to conclude: Either market prices or imputed prices are likely to be off the mark. Where market prices do not exist, one often prefers imputed prices to no prices at all. But in what specific instances to impute prices, how far to go in refining those imputed prices and whether to adjust market prices where they exist depends on one's judgment about the cost and worth of the information. For external effects and public goods, where no market exists at all, I would often be confident that some effort to impute prices is worthwhile. Where market prices exist, even though they are off the mark in terms of the appropriate (but dimly perceived) preferences function, and I would be reasonably confident only in a few instances that derived or adjusted prices would be an improvement over observed prices."[2]

1/ A Legislative History of the Water Pollution Control Act Amendments of 1972, prepared by the Environmental Policy Division of the Congressional Research Service of the Library of Congress (Committee Print 1973, pp. 1456-66.

2/ R.N. McKean "The Use of Shadow Prices" in S.B. Chase, Jr., editor, Problems in Public Expenditure Analyses, Brookings Institution, Washington, D.C., 1968, p. 57-58.

As discussed above, the application of benefit-cost analysis to Federal Government policies which involve human health aspects such as hazardous waste emissions is a complex undertaking. It is useful to review the use of the benefit-cost analysis as discussed above in those Federal Government policies which have resulted in end-product substitution. Two specific Federal Government policies explicitly requested end-product substitution by banning the use of PCB's in transformers and through the outright cancellation of certain pesticides.

As presented in the previous sections of this report, in all of these cases, the Federal Government attempted to explicitly establish the economic impact of its policies by undertaking benefit-cost analysis.[1/] However, in the case of PCB's as well as pesticide cancellations, the emphasis of these benefit-cost analyses was on the economic impact (i.e. costs) on the manufacturers and users of PCB's and pesticides.

The impacts of PCB's and pesticides on the health and welfare of the public was left unanswered in a formal sense, i.e., they neglected to establish morbidity and mortality levels

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1/ In the case of PCB's see: EPA, Support Document/Voluntary Environmental Impact Statement and PCB Manufacturing, Processing, Distribution in Commerce, and Use Ban Regulation: Economic Analysis, Washington, D.C.; Office of Toxic Substances, U.S. Environmental Protection Agency, April 1979.

In the case of pesticide cancellations see: Arnold L. Aspelin, et. al., EPA Pesticide Cancellations and Suspensions: A Survey of Economic Impacts, Office of Pesticide Programs, EPA, March 1980.

associated with the manufacture and use of PCB's and pesticides and translate this information into monetary terms.

To be sure, the health hazards of PCB's and the cancelled pesticides were well established. The use of this information in a formal benefit-cost analysis was not.

It is reasonable to argue therefore, that in the case of the regulations prohibiting the user of PCB's and certain pesticides the Federal Government chose to establish an infinite value for society's health and welfare. Note further, that the relatively modest economic impacts on the manufacturers and users of PCB's and cancelled pesticides essentially allowed the Federal Government to issue relations which outlawed the manufacture and use of these end-products without causing strenuous objections.

More recent regulations by the Federal Government, specifically the Executive Order 12291,[1/] requires that a very comprehensive Regulatory Impact Analysis (RIA)--essentially a benefit-cost analysis which considers all of the alternatives to the proposed federal regulation--is undertaken on all important Federal Government regulations.

Cancellation of selected pesticides and perhaps even the ban on the use of PCB's under Executive Order 12291 would have required a much more complete benefit-cost analysis.

[1/] The President; Executive Order 12291 Federal Regulation, *Federal Register*, Thursday, February 19, 1981, pp. 13193-13198.

Historical Federal Government policies which have led end-product substitution can be readily classified into two major categories:

- Policies and/or regulations which outright prohibit the use of a certain end-product (such as a ban on PCB's) and
- Policies and/or regulations which specify certain performance standards, which in turn lead to end-product substitution (such as fuel efficiency in motor vehicles).

From the point of view of economic efficiency, it has been convincingly argued [1] that the later approach to regulations is much more efficient and can be accomplished with the least cost to both the private as well as public sector. Furthermore, a performance standards approach to regulations allegedly induces innovative and technological change. [2]

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[1] On this see the widely recognized work of J.M. Buchanan and G. Tullock, "Polluter's Profits and Political Response: Direct Controls Versus Taxes", American Economic Review, March 1975, 65(1). See also: S. Rose-Ackerman, "Effluent Changes: A Critique", Canadian Journal of Economics 6, 1973, 512-518; Paul Burrows, "Pollution Control With Variable Production Process" Journal of Public Economics 8, 1977, 357-367; and Roger A. McCain, "Endogenous Bias in Technical Progress and Environmental Policy," The American Economic Review, 68:4, September 1978, pp. 538-547.

[2] This point is well documented in the following studies: C.T. Hill, et al., A State of the Art Review of the Effects of Regulation on Technological Innovation in the Chemical and Allied Products Industries, Vols. 1,2 & 3, Springfield, VA, 1975; and N.A. Ashford, et al., Environmental Safety Regulation and Technological Change in the U.S. Chemical Industry, for NSF by MIT, Cambridge, MA, 1979, and; George C. Eads, "Chemicals as a Regulated Industry, Implications for Research and Product Development", in Christopher T. Hill, Ed., Federal Regulation and Chemical Innovation. ACS Symposium Series 109, Washington, D.C., 1979.

However, as discussed above, the Federal Government elected to use outright prohibition of certain pesticides rather than performance standards in regulating adverse health impacts from pesticide use. The same applies also to PCB's as well as to certain other end-products. [1] There are several reasons advocated for the outright prohibition rather than performance standards of these end-products. [2]

One of these is the fact that the Delaney Clause either outright prohibits or effectively impedes tolerance setting based on risk/benefit for substances that are suspected to be human carcinogens. Thus, performance standards are difficult to apply. Furthermore, in the case of many of these end-products (and especially in the case of pesticides) the generation and emission levels of hazardous wastes are governed not by manufacturers but by numerous users in a large number of locations, i.e. under conditions where performance standards are very difficult or impossible to enforce.

An exception to this occurs in cases where performance standards can be embodied in the end-product which assumes a certain performance without regard to the type of use of the end-product. An example of this would be pesticides formulated in a manner which would guarantee complete degradation within a given period of time.

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[1] These include, among others, DEHP, ethylene oxide (ETO) and ethylene glycol (ETG).

[2] Based on interviews with Emory Lazar, EPA; J.C. Davis, The Conservation Foundation; Richard Morrisson, National Science Foundation.

Note however, that these issues pertain mostly to those end-products which generate hazardous wastes because of a deliberate emission of these end-products into the environment.

However, hazardous waste emission regulation by the use of performance standards may overcome problems in those cases where prohibition of certain end-products (because it generates hazardous waste) results in substitution of another end-product by the manufacturer which also generates different but equally hazardous wastes.

As is clearly indicated in the case studies presented in the previous chapters, this often may be the case. It is also clear that the performance standards approach to regulations of hazardous wastes may be somewhat difficult to administer because of the need to establish clear and comprehensive performance standards.

Finally, there exist a host of other government policies and regulations which would reduce or eliminate hazardous waste generation, but which the Federal Government has not yet attempted to undertake. These include among other, the following:

- Tax and other financial incentives for the industries to undertake R & D efforts for the purpose of developing end-products with reduced hazardous waste generation characteristics;

- Penalty taxes (surcharge) on end-products which generate hazardous wastes, levied on purchasers of such end-products and/or on firms which manufacture such end-products;
- Various types of government subsidies for the manufacturer of substitute and superior end-products which generate reduced levels of hazardous wastes;
- Priority listing of end-products which generate hazardous wastes with a timetable requiring that substitute end-products be developed during the specified time and enforced by increasing penalties to the manufacturers;
- Requirement that the manufacture of certain end-products which generate hazardous wastes be undertaken only in certain locations when the emission of said wastes would result in minimum environmental damage;
- Comprehensive public information campaign informing the public to purchase end-products which generate lower levels of hazardous wastes, and;
- Implementation of value added tax for end-products which generate hazardous wastes to be levied at manufacturers which use said end-products.

There are, of course, other policy/regulatory options available to the Federal Government, but those enumerated above should indicate the range of regulatory policies available to the Federal Government, as yet not tried.